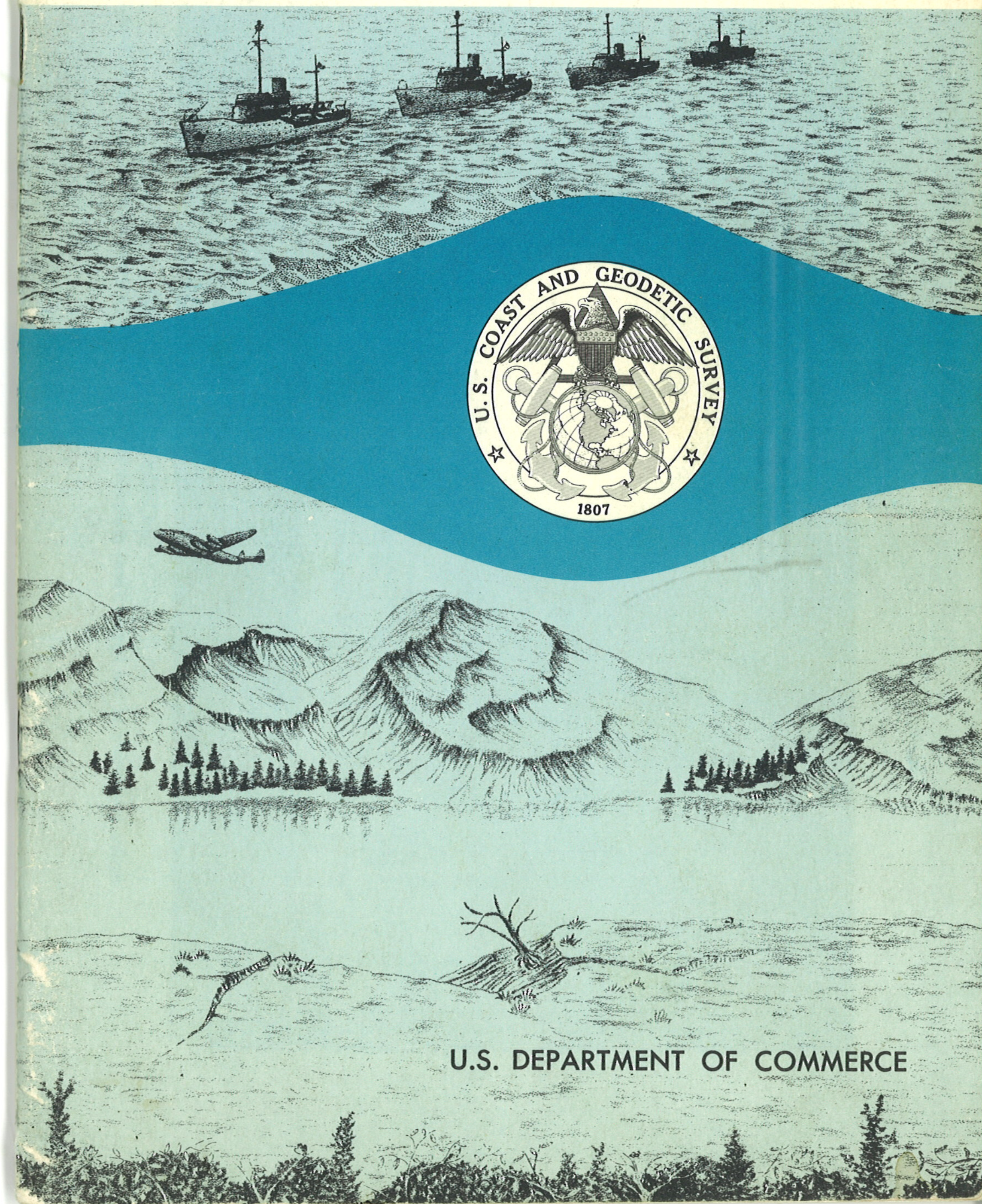
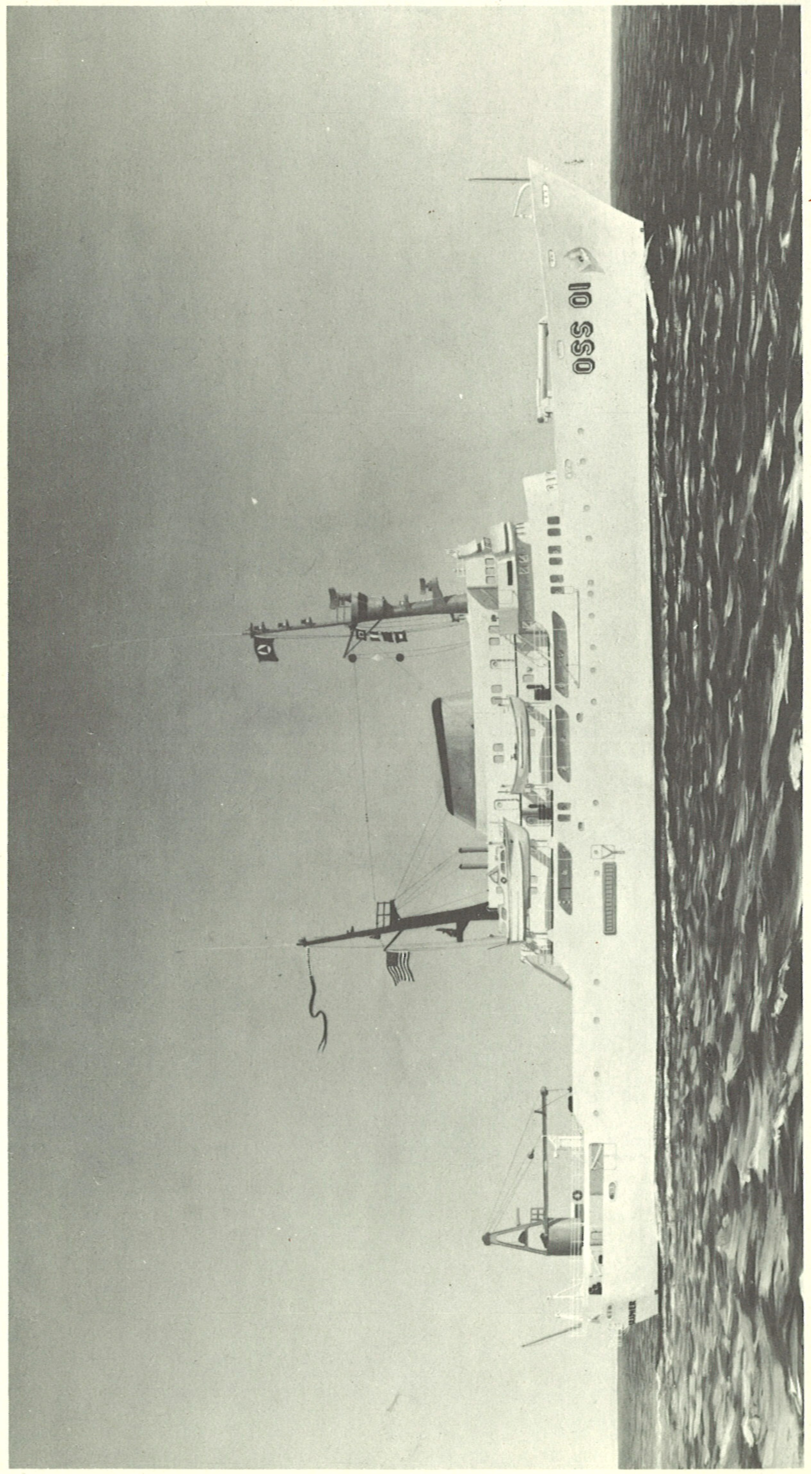
THE COAST & GEODETIC SURVEY

its Products and Services



U.S. DEPARTMENT OF COMMERCE



USC&GSS *Oceanographer*
Artists conception of the largest vessel designed for oceanographic surveys to be built in the United States.

The Coast and Geodetic Survey
Its Products and Services

Publication 10–2

U.S. DEPARTMENT OF COMMERCE
JOHN T. CONNOR, SECRETARY

COAST AND GEODETIC SURVEY
H. ARNOLD KARO, DIRECTOR

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The varied activities of the Coast and Geodetic Survey in the fields of engineering, science, and higher mathematics are essential to the day-to-day operations of large segments of the Nation's business and industry. The Bureau has contributed much to our American heritage through progressive scientific and engineering accomplishment over almost 16 decades of public service. Work in measuring the physical characteristics of land and sea has provided a national basic profile of our present environment and is essential to future expansion.

The principal products of the Survey are nautical and aeronautical charts which are basic tools in maintaining the Nation's air and sea transportation systems. In addition to being indispensable to the maritime and aviation industries, these products and technical services are requisites in planning and operating extensive programs in other forms of communications, development of natural resources, hydrography and oceanography, agriculture and reclamation, public works and urban planning, and other programs affecting economic development. Thus this highly technical bureau directly aids the Department of Commerce in carrying out the mandate from Congress to promote, foster, and develop the industry and commerce of the United States. Principal areas supported by the Bureau are the maritime, aviation, fishing, and petroleum industries, transportation and construction.

Safe transportation is a necessary aspect in the economic development of a nation. Expeditious movement of people and goods with safety is essential to any significant economic and social activity. The Bureau recognizes that keeping abreast of technological progress in all aspects of modern civilization is essential to economic growth.

Ships and their cargoes navigating American waters have an annual value exceeding $100 billion. Nautical charts are vital in safeguarding this huge volume of water traffic against thousands of dangers which beset these vessels. The coasts are rendered still more dangerous by rapid tides and eddies peculiar to the American seas and by strong alongshore currents. Therefore, to supplement the nautical charts, sailing directions or coast pilots, tide tables, tidal current tables, and tidal current charts are published. These services are also important in establishing marine insurance rates. Another factor having a direct bearing on the profits and losses of the marine industry is the time element involved in moving cargoes between ports. Adequate surveys indicate the shortest possible safe routes, close to shore, which have a considerable economic advantage.

Aeronautical charts support air commerce and civil aviation with the same standard of accuracy and efficiency as found in the nautical charts.

Aircargo carriers require official distances between airports to serve as a basis for ratemaking. They also are provided by the Bureau with detailed information concerning the obstructions, length of runways, and other important data concerning airports to determine the safe takeoff capacities of loaded transport planes.

The Coast and Geodetic Survey has provided unique service to the petroleum industry. The discovery and exploitation of new oil-bearing regions are aided by the special services rendered by the Survey. Basic triangulation and leveling lay the groundwork for subsequent geologic and topographic mapping in potential oil areas. Techniques and principles developed by seismological studies aid in locating oil-bearing strata. Essential to the discovery and exploitation of petroleum are topographic and planimetric maps in coastal areas and hydrographic surveys in offshore areas. Photogrammetric surveys, coordinated closely with tidal observations and leveling, aid in the location of drilling sites and indicate allowances to be made for various tidal conditions.

The fishing industry receives substantial assistance through geological oceanographic investigations of the continental shelf. These investigations provide the industry with a new type of information on sea bottoms, the great offshore fishing banks, and the oceanic areas adjacent to all the coasts of the United States. This information has already resulted in increased productivity of the industry, including the discovery of new fishing grounds.

In addition to air and waterborne commerce, the Survey provides vital services through geodetic surveys to the vast highway system of the Nation. A current and very important use of geodetic surveys is now evident in connection with the Interstate Highway Program. Geodetic control is being established along the proposed routes of the interstate highways with some 7,500 miles now completed. This work serves as a basis for all large-scale strip mapping along the highway routes and for detailed engineering surveys associated with highway construction.

In the construction industry, many cities—particularly those now undergoing rapid expansion—rely upon geodetic surveys for the basis of large-scale mapping not only in the city itself but the outlying regions as well. These surveys also provide accurate coordinates on which all city engineering surveys for construction, land acquisition, land development, and the like are based. Seismological studies and investigations are carried on for the purpose of mapping earthquake areas and to evaluate earthquake risks through the operations of seismographs and systematic collection of earthquake data.

The Seismic Sea-Wave Warning System operating in the Pacific is an example of far-reaching planning by the Bureau to insure safety and stability in support of economic progress in an important segment of our national domain.

The demands upon the Survey have grown with the national progress of the United States whose shoreline is now over 80,000 miles in length. Since

its inception in 1807, added responsibilities have come with the addition of: the Florida Purchase (1819), the Texas Accession (1845), the Oregon Territory (1846), and Mexican Cessions (1848), the purchase of Alaska (1867), the Hawaiian Accession (1898), and the addition of Puerto Rico, Guam, and Philippine Islands (1898), Samoa Islands (1900), the Canal Zone (1903), and the Virgin Islands of the United States (1917).

Early History

During the very early sessions of Congress it was recognized that a national duty must be performed. Foreign commerce and coastwise traffic were substantial, even for that time. Heavily laden vessels with their precious burdens were entering and leaving our ports for every part of the world. Through the years the wisdom of undertaking a survey of the coast had become increasingly evident, as it was realized that benefits would accrue not only to commerce, industry, and engineering but to the national defense of the country as well.

Commerce and industry in the formative days of the Nation were concentrated along the Atlantic coast with waterborne traffic the principal means of transportation. This resulted in a pressing need for accurate knowledge of the coast and adjacent waters to promote safety in navigation and to expedite waterborne commerce between the several States and with foreign countries. The charts, which were primarily of foreign publication, were drawn from information obtained previous to the American Revolution. These were imperfect sketches of such ports as the policy of the British Government had caused to be surveyed during the colonial period. They were few in number. In general the mariners were left to acquire their knowledge from the shipwrecks of others.

The origin of the Coast Survey can be traced to the report by a special committee of the Third Congress, on February 27, 1795, which stated that, the seacoast, not only of Georgia, but also of South Carolina, North Carolina, and Virginia, had never been surveyed with the requisite accuracy, and concluded with a recommendation for the adoption of resolutions which should request and authorize the President to cause a survey to be made of the coast between Chesapeake Bay and St. Mary's River. An additional report of like tenor was made to the Fourth Congress. During the Ninth Congress on December 15, 1806, a Representative from Connecticut addressed the House upon the need for a survey of the whole extent of the coast of the United States. Such a bill was reported out of committee on January 6, 1807, and after amendment was approved by President Jefferson on February 10, 1807. Thus was born the "Survey of the Coast."

The Secretary of the Treasury, in whose department the new organization was assigned, requested plans for the survey of the coast from known men of science of that period. Among those solicited was Ferdinand R. Hassler, a Swiss engineer, who had arrived in the United States in October 1805 and was at the time of the request professor of mathematics at West Point. Hassler's plan was one of seven given serious consideration. It reflected a thorough grasp of the problems involved based on his experience while doing field work on a trigonometric survey of Switzerland, and in a thorough study of the entire field of geodesy. He was internationally recognized in this field. Upon the recommendations of the American Philosophical Society, the Hassler plan was adopted and he was appointed the first superintendent of the new agency.

Due to the unsettled conditions prevailing at the time, plans for the survey were delayed for several years. Special preparations were required for the enormous task, including the procurement of instruments and equipment. The necessary items were not available in this country, and Hassler was compelled to go to England and France for them. He left for Europe in August 1811 and was unable to return until late in 1815. He spent his time supervising construction, testing, and standardizing the instruments built in accordance with his designs.

At that time when surveying was incomparably cruder than it is today, the first superintendent realized the magnitude of the job he was undertaking. His plan required the execution of a system of triangulation along the coast by which all detailed surveying operations thereafter undertaken would be controlled in accuracy, with each separate unit fitting exactly into the overall scheme. The control surveys of this country were thus begun and since that time all topographic and hydrographic work undertaken by the Survey has been rigidly controlled by triangulation.

Fieldwork was started in 1816 with measurements of geodetic base lines at Gravesend Village, Long Island, and near English Creek, N.J. A small network of triangulation was developed in the vicinity of the city of New York. Following this modest beginning, all activities of the new bureau were transferred in 1818 from the Treasury Department to the Navy Department. Work accomplished was severely limited until 1832 when Congress enacted new legislation extending the scope of the 1807 act and reactivating the agency under the Treasury Department.

By this time Florida had been added to the Union and its long coastline was included in the total to be surveyed. Furthermore, the military value of the work in coastal defense was recognized and provision was made therefor. Hassler resumed his task with renewed vigor, aided by officers of the Army and the Navy. The network of geodetic control so vital to all the work was extended southward along the Atlantic seaboard. When Professor Hassler died in 1843, the triangulation net extended east to Rhode Island and south to the head of Chesapeake Bay, including the critical areas of Delaware Bay.

Period of Expansion

In 1833 James Ferguson, who had assisted in the survey of the boundary between the United States and Canada, was appointed the first principal assistant in the Coast Survey. As chief of a field party, he conducted surveys

along the north shore of Long Island Sound, while Edmund Blunt, the other principal assistant to Superintendent Hassler, headed a party on Long Island. Four maps were published in 1834, at the scale of 1 : 1,000,000 showing the triangulation scheme in the vicinity of New York, Long Island, and the Connecticut shore, but hydrographic details of the offshore areas were not included.

The first hydrographic survey was conducted in 1835 by the schooner *Experiment,* under the command of Lt. Thomas R. Gedney, in Great South Bay and along the south shore of Long Island. The brig *Washington* was the first Coast Survey vessel to be used extensively in oceanography. The brig was constructed in 1837 for use as a revenue cutter, but served in that capacity only during the winters of 1837, 1838, and 1839. During the summers of those years the vessel was assigned to the Coast Survey for temporary duty; in April 1840 she was formally transferred to the Survey.

Topographic surveys based upon the control established in former years were conducted during 1836–38 on Long Island and along the coast of New York, Connecticut, and New Jersey. Copperplate engraving was added to the activities of the Coast Survey and in 1842 the first copperplate printing press was obtained. The first chart of New York Bay and Harbor was engraved and issued in 1844.

Prof. Alexander D. Bache became the second Superintendent of the Coast Survey in 1844. At that time surveys had been extended into nine States, with plans for extending the work into four additional States. During the summer of 1846, under the direction of Professor Bache, the first orderly scientific investigation of the Gulf Stream was undertaken. In 1769, Benjamin Franklin, who was the great-grandfather of Professor Bache, directed the attention of the scientific world to the existence of the Gulf Stream.

Reconnaissance preliminary to the survey of the coast of the Gulf of Mexico was started in 1845, and the coast between New Orleans and Mobile was thoroughly examined. Upon acquisition from Great Britain in 1846 of the Oregon Territory and from Mexico in 1848 of the California Territory, surveying the Pacific coast of the United States became an added responsibility of the Coast Survey. The first such survey was started in 1848. Rapid strides were made in copper engraving of charts for various coastal areas and harbors. Many of the copperplate engravings executed over 100 years ago reflect the finest techniques in past methods of chart reproduction. The "age of copper engraving," which afforded a beginning to the artistic career of the renowned James McNeill Whistler, was the most romantic period in American cartography.

Anticipating the acquisition of Alaska from Russia, the Coast Survey made extensive plans for surveying the waters and coastal regions of the new territory. When formal transfer of Alaska to the United States was made in October 1867, George Davidson, an assistant in the Survey, and a surveying party had already spent the summer of that year in Alaskan waters with the revenue cutter *Lincoln.* The Davidson party made numerous observations and as a result of the season's work, charts were published of Sitka and St. Paul Harbors and Kodiak Island. The first Coast Pilot of Alaska was published in 1869 based on the investigations by Davidson. Between 1867 and 1882 the Coast Survey compiled and published numerous charts of Alaskan waters.

Continuous operations were started in 1882 when the ship *Hassler* was sent north. The ship *Patterson* was assigned to Alaskan waters in 1885 upon her acquisition by the Bureau. During this period, triangulation, topographic, and magnetic surveys were conducted, in addition to hydrographic investigations. Upon discovery of gold in Alaska, the rush to the Klondike region in 1897 was served by a survey of the beach at Nome which had been made by Coast Survey ships. The gold rush created new interest in the territory and the Survey was given increased appropriations with which to carry on and expand its Alaskan work.

By an act of Congress in 1871 the Bureau was given the added responsibility of providing geodetic control for the interior of the country, and in 1878 the name was changed from U.S. Coast Survey to U.S. Coast and Geodetic Survey. At the close of the Spanish-American War, the Coast and Geodetic Survey was ready to proceed with the important work of surveying and charting the waters of the Philippine Islands. From 1900 to 1940 much of the original work in surveying the Philippines area was accomplished.

Under normal conditions the work of the Coast and Geodetic Survey is carried on chiefly in the interest of commerce and industry, but with the advent of war it becomes necessary to rechannel all activities in order to concentrate on projects essential for war purposes. Adjustments are made in the volume of work during war periods to enable the Survey to meet the strategic needs for its products and services.

All activities carried on during World War II were planned for maximum contribution to the war effort. Many special programs were carried out by the field and office forces as the Survey's contribution to the war effort. Aeronautical charts of various types and at different scales to meet specific requirements were produced for a large part of the world.

Following the war, the change to electronic methods in the field and office was accelerated.

In 1961, the Coast and Geodetic Survey was reorganized for the purpose of extending and exploiting the scientific and technological potential of the Bureau. The new organizational structure provides for major shifts in program direction with emphasis on oceanography and scientific research in the various areas of Bureau responsibility. The reorganization was designed to meet the needs of this modern and revolutionary age of science and technology.

Organization and Functions

The organization of the Coast and Geodetic Survey is comprised of two forces—office and field. The Director as the administrative head of the

Survey is responsible for all phases of the work, including standards of performance, efficiency of operations, fidelity of work, and the expenditure of appropriations.

The office organization is comprised of the offices of the Director, Deputy Director, 5 Assistant Directors, and 17 divisions. The five offices, each headed by an Assistant Director, and its component divisions are as follows: Oceanography—Operations, Marine Data, and Facilities; Physical Sciences—Seismology, Geodesy, Geomagnetism, Electronic Computing, and Photogrammetry; Cartography—Nautical Chart, Aeronautical Chart, Reproduction, and Distribution; Administration—Administrative and Technical Services, Budget and Finance, Engineering, Management and Organization, and Personnel; and Research and Development.

Office of Oceanography.—This Office plans, coordinates, and directs oceanographic surveys and related control surveys; administers and supervises the analyzing and processing of the resulting data; compiles and publishes marine publications and reports; operates jointly with the Office of Physical Sciences the Seismic Sea-Wave Warning System; plans and provides the operating facilities for the collection of oceanographic and other related data; conducts research in oceanography and related operational facilities, in accordance with the plans and assignments of the Bureau's overall research and development program. This Office is organized into the following three technical divisions:

The Operations Division plans, writes instructions for, and supervises the execution of oceanographic and related control surveys. These surveys include the observations, study, and recording of the hydrography and the physical and chemical properties of sea water; the determination of the geology of the ocean bottom; the study of marine sedimentation of the ocean's bottom; the recording of gravimetric and magnetic phenomena at sea and the collection of other data for charting, navigational, and scientific purposes. The Division plans and supervises the operation of survey ships and shore based parties for obtaining soundings, observing tides and currents, securing ocean water and bottom samples; making gravimetric and magnetic observations, conducting Coast Pilot field examination, measuring water temperatures, collecting marine-life specimens, and making meteorological observations. It maintains a system of control tide stations and collaborates in the operations of the Seismic Sea-Wave Warning System.

The Facilities Division plans and provides the operating facilities, including ships, small vessels, and ship bases, required for the collection of oceanographic data. It plans, designs, supervises and inspects the construction (except new ship construction) and major repairs of the operating facilities. It also maintains the construction, operational, maintenance, and historic records of these facilities.

The Marine Data Division administers and supervises the analysis and compilation of oceanographic data, including the preparation of oceanographic and marine navigation publications. This includes the investiga-

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tion of oceanographic phenomena through the study of recorded observations; the compilation and publication of tide and tidal current tables, tidal current charts, sea water temperatures and density summaries, Coast Pilots, distances between U.S. ports, and seismic sea wave traveltime charts. The Division participates in planning of oceanographic surveys, control tide stations, and the Seismic Sea-Wave Warning System. It determines, compiles, and evaluates oceanographic data from other sources both domestic and foreign; and conducts research in oceanography.

Office of Physical Sciences.—This Office provides geodetic, geophysical, and cartographic data for charting and scientific purposes and for defense needs. It plans, coordinates, and directs the maintenance, adjustment, and extension of the geodetic control network including astronomic observations and gravity surveys; recording and investigation of magnetic and seismological phenomena; photogrammetric mapping; operation of the seismic sea wave warning system, in collaboration with the Office of Oceanography; investigations relating to astronautics; operation of latitude observatories, magnetic and seismological observatories, and laboratories, and seismological stations; operation of automatic data processing facilities; and office processing and analysis of survey data, including compilation, publication, and distribution of geodetic control data, photogrammetric measurements and compilation of maps; compilation and publication of magnetic and seismological reports; and compilation and publication of other reports as required. It conducts research in the physical sciences, in accordance with the plans and assignments of the Bureau's overall research and development program. This Office is organized into the following five divisions:

The Geodesy Division plans and executes field geodetic surveys including triangulation, traverse, leveling, base measurements, astronomic observations, and gravity determinations; operates two astronomic observatories for the determination of the variation of latitude; processes field observations and other data for publication in suitable form required by the Bureau, other Government agencies, and the public; conducts research activities involving high-altitude gravity, figure of the earth, earth-satellite geodesy, mathematics of projections, variation of the axis of rotation of the earth, combined trilateration and triangulation, and analysis of earth movement surveys; develops and recommends, for consideration by the Program Planning Staff, long-range plans for geodetic control programs. The Division also consults with and advises local governments and Federal agencies on all types of geodetic problems, from control surveys, in all its aspects, to highly scientific problems related to intercontinental missiles, earth satellites, and physical geodesy.

The Photogrammetry Division operates aircraft for aerial photography; does coastal mapping for the nautical chart program; makes airport surveys for the production of airport obstruction charts and turbine data sheets, and for the location of aids to air navigation; makes photogrammetric measurements and computations for satellite triangulation; does analytic

aerotriangulation for control of mapping, and for special projects such as the study of earth crustal movement, boundary locations, and cadastral surveys; makes photogrammetric tidal current surveys; makes office photogrammetric measurements, and compiles map and survey data for various Bureau programs; and distributes aerial photographs and survey information to the public. The Division provides photogrammetric consultant services to Federal, State, and local agencies. It conducts research and development activities to improve the accuracy and to broaden the application of photogrammetry to Bureau and national programs.

The Geomagnetism Division plans and conducts the operations pertinent to the Survey's responsibilities in geomagnetism. A substantial part of their work is devoted to research and development. The operations include not only the work of field parties making magnetic measurements, but that of magnetic observatories where continuous records of changes in the earth's magnetic field are made. Most of the observatories are equipped with seismographs and thus constitute cooperative installations that are supported jointly by the Geomagnetism and Seismology Divisions. The Honolulu Magnetic and Seismological Observatory, however, is under the jurisdiction of the Seismology Division because of its importance as the field headquarters of the Seismic Sea-Wave Warning System. Magnetic work includes the establishing of permanently marked magnetic stations (observing points) where the strength and direction of the magnetic field are measured; the design, development, testing, and standardization of instruments; the maintenance of international magnetic standards; collection of magnetic data from the entire world and compilation of world magnetic charts in collaboration with the U.S. Naval Oceangraphic Office; and conduct of basic research to develop new theories and knowledge regarding the configuration of the magnetic field and the electrical systems that produce and modify the field.

The Seismology Division plans and directs the technical functions of magnetic observatories (as they relate to seismology) and seismological field parties; operates and maintains strong-motion and teleseismic seismographs, and maintains tilt-meter stations; analyzes and processes records from strong-motion and teleseismic stations; collaborates with seismological observatories in foreign countries, for the purpose of determining earthquake epicenters and exchanging seismological data, and serves as one of the international depositories for such data; compiles, publishes, and distributes reports and studies pertaining to seismological phenomena; and participates in the operation of the Seismic Sea-Wave Warning System. The Division also conducts special seismological monitoring projects and studies in connection with the national defense and security; tests and calibrates seismological instruments; prepares plans and directions for the installation and operation of seismological equipment and stations; and conducts research in seismology and related instrumentation, collaborating with the Engineering Division with respect to instrumentation.

The Electronic Computing Division plans and conducts automatic data processing activities involving the solution of mathematical problems, the compilation of scientific and technical data, and the processing of fiscal accounts and payrolls; conducts these activities in accordance with established or tested programs, instructions furnished by the other divisions, or programs developed within the Division; analyzes problems to determine the most feasible method of solution, and schedules the steps and operations; and prepares machine instruction cards, wiring, and procedure diagrams, and codes. The Division reviews the processed results for completeness and accuracy.

Office of Cartography.—This Office provides charts for marine and air navigation to meet civil requirements and defense needs; plans, coordinates, and directs the compilation and maintenance of nautical and aeronautical charts, the operation of a chart-reproduction plant, and the administration of chart-distribution facilities; and conducts research in cartography and the graphic arts, in accordance with the plans and assignments of the Bureau's overall research and development program. This Office is organized into the following four divisions:

The Nautical Chart Division plans and directs the construction and maintenance of nautical charts from the original hydrographic and topographic surveys of the Bureau and surveys or information from other sources; registers, verifies, and reviews the hydrographic (including wire-drag) and topographic surveys of the Bureau; furnishes information for hand correction of charts before issue; and cooperates with the Naval Oceanographic Office and Coast Guard in the preparation of the weekly *Notice to Mariners*.

The Aeronautical Chart Division plans and directs the construction and maintenance of aeronautical charts and related publications to meet the requirements of civil-military aviation. It acquires, evaluates, and selects basic source material concerning air navigation for use in chart construction; and periodically flight-checks aeronautical charts for accuracy.

The Reproduction Division plans and directs integrated printing facilities for the lithographic reproduction of charts and maps; engages in and utilizes all processes for making a lithographic copy from a manuscript, which includes negative engraving, type composition, photographic processes, platemaking, and multicolor press operation.

The Distribution Division plans and directs the distribution of new and current issues of nautical and aeronautical charts, maps, tide and tidal current tables, and related publications to other agencies, contract sales agents, and the public. It performs the finishing functions of trimming, folding, punching, collating, and packaging, preparatory to issuance of charts; imprints hand corrections on nautical charts; and performs accounting and other clerical work pertaining to distribution of charts, publications, and miscellaneous photographic work. The Division directs the establishment and inspection of sales agents.

Office of Administration.—This Office is responsible for the overall planning, coordination, and direction of the administrative and certain technical

support functions. The administrative support functions include organization, management communications, and internal audit; budget, finance, and accounting; personnel recruitment, placement, training, and relations; and procurement and supply. The technical support functions include instrument and equipment development, construction, and maintenance; and library and map reference services. This Office is organized into the following five divisions:

The Administrative and Technical Services Division procures supplies, equipment, and services; receives, stores, and issues supplies and equipment; provides general office services; conducts a records, forms, and reports-management program; and conducts a motor vehicle and property management program; conducts a program to promote safety practices throughout headquarters and the field; maintains the Bureau library, the archives of technical and scientific records, and an extensive map file; provides reference service for cartographic source data and other related information, including geographic names research, special illustrations and cartographic work for publications and other purposes; answers general inquiries by providing information concerning the Bureau's work, products, and services; and prepares exhibits for public display.

The Budget and Finance Division develops, formulates, and executes the Bureau budget and establishes and maintains a bureauwide system of accounting. It prepares the Bureau estimates, justifications and other supporting data; assists in the budget presentation; evaluates the execution of the budget and recommends apportionments and allotments of funds by program. The Division maintains expenditure and obligation controls and accounts; maintains cost accounts for Bureau projects; administers payroll and leave functions; and performs related fiscal activities including the examination, audit, and certification of vouchers.

The Engineering Division works closely with all operating divisions to develop, procure, and provide the survey instruments, and equipment required for the Bureau's programs in oceanography, geodesy, photogrammetry, geomagnetism, seismology, and cartographic compilation and reproduction. It designs, develops, and constructs much of the Bureau's instrumental equipment, which includes mechanical, optical, and electronic components. In addition, it develops specifications and prototype models of new types of equipment to be made by commercial firms; and it tests and makes recommendations for the procurement of stock and custom-made commercial equipment. This Division is also responsible for keeping the Bureau's instruments in good working order, maintaining special repair and test facilities for this purpose.

The Management and Organization Division provides various types of staff assistance to the Director and other Bureau officials. It makes special surveys and studies relating to organization, staffing, methods, and systems, workflow, and other management matters to promote efficiency and economy throughout the Bureau. This Division also prepares, reviews, and coordinates all internal management and administrative instruction and regulations.

The Personnel Division provides the administration of civil service personnel for the Bureau. It recruits, trains, and places new employees; maintains the official personnel records; describes and classifies each civil service position according to duties and responsibilities; and conducts the Bureau's employee incentive program, which encourages and evaluates employee suggestions and meritorious service. The Division also provides special services in the way of employee relations, such as insurance and retirement counseling, hearing of employee grievances, and other personal assistance to employees.

Office of Research and Development.—This Office plans, initiates, administers, and supervises the Bureau's overall basic and applied research and development program in fields of interest to, or within the competence of, the Coast and Geodetic Survey. This includes, but is not limited to, research and development in cartography, oceanography, geodesy, geomagnetism, seismology, photogrammetry, gravimetry, astronautics, and related supporting fields such as mathematics, astronomy, physics, chemistry, marine biology, photography, electronics, optics, mechanics, automatic data processing, survey techniques, instrumentation, and ship and observatory construction and operation. The Office develops, applies, and disseminates resulting findings, theories, and hypotheses; collaborates with and makes recommendations to the Program Planning Staff concerning research and development and with the other Offices and Divisions in planning research and development to meet their requirements; directs, assigns, and coordinates all research and development within the Bureau; investigates the capabilities and facilities of commercial and nonprofit firms and institutions for performing research and development for the Bureau, and initiates specifications and working agreements for such services; and consults, advises, and cooperates with other Federal agencies and public and private institutions in aspects of research and development in which the Bureau is interested or qualified.

Regional Offices.—The Coast and Geodetic Survey has divided the area over which it has cognizance into four regions, with the regional offices located in Norfolk, Kansas City, San Francisco, and Seattle. The regional offices embody the general concept that they will be responsible for the day-to-day technical, logistical, and administrative operations of its assigned units under the overall policy, program planning, and general guidance provided by Bureau headquarters.

Usually, mobile parties come under the operational direction of the regional office responsible for the area in which they are operating. Eventually, the program work for each area will be assigned to the regional office which will provide the detailed project and operating instructions for execution of the program.

Within the area assigned to each of the regional offices are the following field offices: Norfolk Region—Boston and New York; Kansas City Region—New Orleans; San Francisco Region—Los Angeles and Honolulu; Seattle Region—Portland and Anchorage.

Personnel

Personnel of the Coast and Geodetic Survey consist of two major groups—commissioned officers and civil service employees. Employment is in the Washington office and in the field service throughout the 50 States of the United States, its territories and possessions.

On July 1, 1964, the Coast and Geodetic Survey had 217 commissioned officers and 2,855 civil service employees. Of these, about 1,200 were on duty in the Washington office, approximately 250 were assigned to permanent field installations, and the remainder were engaged on fieldwork attached to vessels and mobile field parties.

Commissioned personnel include the Director of the Bureau, who is a rear admiral (upper half) and the Deputy Director, who is a rear admiral (lower half); other officers range in rank from captain down through ensign. These officers, who are all engineers with additional technical training in the specialized work of the Bureau, hold administrative and key positions both in the Washington office and in the field service.

Recruitment of Officer Personnel.—Initial appointment in the Bureau is normally in the position of deck officer. Candidates for appointment must be citizens of the United States, must not have received an induction notice, must be physically qualified, and, unless given a waiver, must be between the ages of 20 and 26 years. A prerequisite for consideration for appointment is a degree from: a college or university accredited by the Engineers Council for Professional Development, a national military academy, or a Federal or State maritime college. The degree awarded must be in the field of civil, electrical, or mechanical engineering, physics, mathematics, oceanography, or a related scientific subject. In cases where an applicant has taken graduate studies leading to an advanced degree in one of the above fields, or has had previous professional experience in a field related to the Bureau functions, the age limit may be increased correspondingly to a maximum limit of 36 years. Veterans may be allowed further waivers of the maximum age limit.

Deck officers complete a formal training course of from 12 to 16 weeks prior to their first duty assignment. The course is scheduled several times annually. Normally, deck officers are commissioned as ensigns prior to the completion of this course, unless previous experience or advanced education warrant initial appointment at a higher grade.

The duty assignment following the training course will be with a shore field party or aboard a ship engaged in any of the numerous scientific operations of the Survey.

The qualifications and eligibility for appointment and promotion of commissioned officers are examined by a board appointed by the Secretary of Commerce, consisting of not less than five senior commissioned officers of the Survey.

Civil service personnel are divided into four groups: professional employees including cartographers, engineers, geophysicists, geodesists, mathematicians, oceanographers, and physicists; technical employees comprising cartographic aids, survey aids, draftsmen, scientific aids, instrument makers, press operators, lithographic artists, and other employees specially trained in reproduction methods; administrative, clerical, and custodial employees including personnel specialists, budget specialists, administrative officers, accountants, management analysts, secretaries, stenographers, clerks, and messengers; and crewmembers attached to the vessels of the Survey.

Selection of Civil Service Personnel.—The majority of the employees of the Survey are selected through examinations given by the Civil Service Commission. Field employees not recruited through the civil service system are employed for short periods of time by chiefs of mobile field parties who recruit locally in the area in which the field party is in operation. Recruitment of vessel personnel is conducted by the commanding officers of the various vessels at their home ports without recourse to civil service registers.

Personnel Training.—In selecting personnel for employment in the Survey, great care is exercised to obtain the candidate with the best possible qualifications for each position. Due to the specialized nature of the work, it is not possible to obtain personnel who can, without additional training, assume the full responsibilities of many of the positions. Consequently, a comprehensive training program has been established in the Bureau. This consists of the establishment of special classroom training, formalized on-the-job training, rotation of assignments to other phases of work, payment of fees for attendance at colleges and universities, and utilization of training facilities of other Government agencies.

Safety.—Because of the unusually hazardous nature of much of the work of the Bureau, the aggressive pursuit of a positive safety program is considered a major responsibility of the management of the Bureau. This function is aligned with the personnel program since it ties in closely with the training function and the physical examination given to new personnel and field personnel on a regular periodic basis. The Safety Officer is assisted by a Safety Committee comprised of representatives of the operating divisions and by deputy safety officers throughout all activities including field parties and vessels. It is a Bureau policy to look to all supervisory personnel to provide the real safety leadership in daily operations, with the safety officer, his deputies and committee serving as advisers and offering assistance in the implementation of the program.

Surveying Vessels and Equipment

For well over a century, vessels of the Coast and Geodetic Survey have carried on extensive surveying operations in the coastal waters of the United States and its farflung territories and possessions as they became part of the Nation.

Before the turn of the century, sailing vessels were used extensively in conducting hydrographic surveys. The change from sail to steam and from wood to iron resulted in an immense difference in the efficiency and capabilities of the surveying ship. Gradually steam-driven vessels came into general use until sail completely disappeared during the early part of this century. For the past 60 years the surveying fleet has been almost entirely dependent on steam. Great were the handicaps under which the early surveys were executed and it is astonishing that so much accurate and detailed information was obtained and charted.

The historical record of the Survey notes many instances of great hardship encountered in surveying our coastal waters. An outstanding experience, when great courage and endurance were displayed under extremely hazardous conditions was during the near-loss of the brig *Washington* in 1846. After her successful cruise in the Gulf Stream during the summer of 1846, she was caught in a hurricane during her return to port. The brig was severely damaged and would have been lost except for the supurb seamanship of both officers and crew. After foundering for more than a week, the vessel reached port but not before the commanding officer and 10 members of her crew were lost.

Among the last of the sailing vessels used in Coast Survey work was the schooner *Matchless,* which was regarded as the most handsome of the sailing fleet. She was a two-masted centerboard vessel, measuring 97½ feet in length with 24¼-foot beam and 8-foot depth of hold. The vessel was elaborately furnished throughout with roomy quarters for officers and crew. The chartroom was large and bright. For many years the vessel was used as a training ship.

In late 1847, the Coast Survey first used a steam-driven vessel in hydrographic surveying. She was the *Bibb,* of wood construction, and operated along the east coast of the United States. The *Jefferson,* the first Coast Survey steam vessel of iron construction, was obtained in July 1849.

At the beginning of the present century the Coast and Geodetic Survey had in service a number of specially built steam-driven surveying vessels. In addition to the coastal waters of the United States, these vessels were used extensively in Alaska and the Philippine Islands. Much of the original work in surveying the coasts and adjacent waters of the Philippines was accomplished by our fleet of surveying vessels.

At the outbreak of World War I, selected vessels of the Coast and Geodetic Survey were transferred to naval duty. The *Surveyor* was one of the vessels taken over by the Navy and was especially active on extensive escort and convoy duty in the Atlantic Ocean and Mediterranean Sea. Manned by

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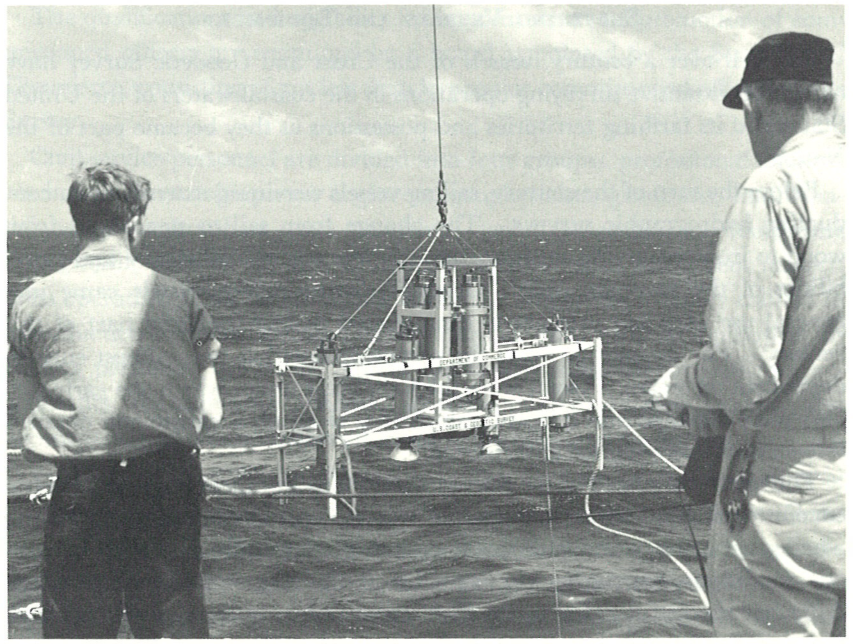
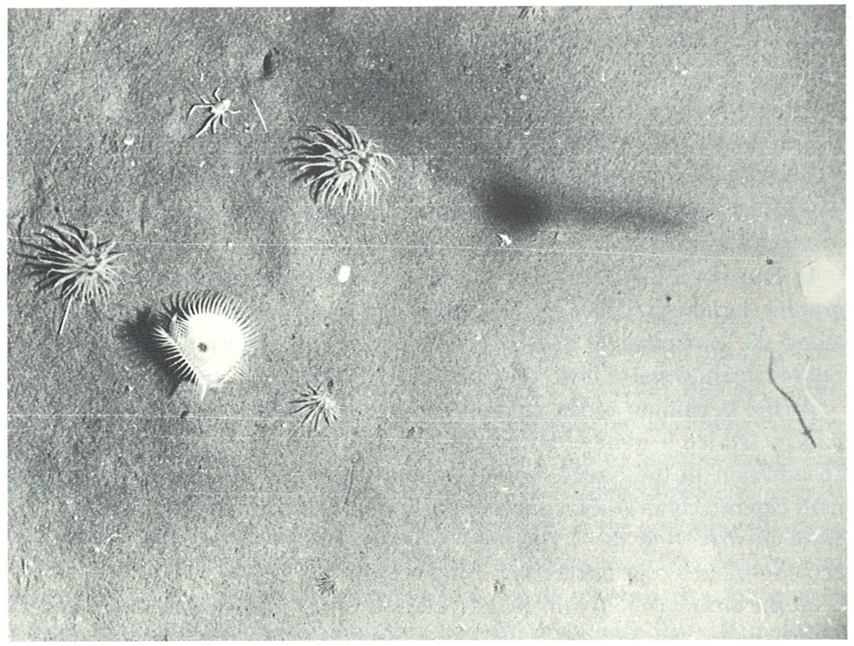


Deep-sea camera going over the side of an oceanographic survey ship. Photograph shown below taken by this camera.



Underwater photograph taken at a depth of 260 fathoms in the Atlantic about 80 miles off Nantucket Island.

officers of the Survey, the ship participated in several submarine engagements, including an attack in May 1918 by two German submarines on a convoy to which she was attached as an escort. One of the submarines, the *U–39,* which had previously sunk the *Lusitania,* fired a torpedo at the convoy which grazed the bow of the *Surveyor.* The wake of the submarine was picked up by the *Surveyor* and she was able to deliver an effective depth charge. The vessel could not leave the convoy to finish off the submarine, but the U-boat was disabled to the extent that it was compelled to enter the port of Cartagena, Spain, there to be interned.

The surveying fleet in operation late in 1964 comprised 14 ships consisting of 5 ocean survey vessels ranging between 2,000 and 3,000 displacement tons, with the balance made up of smaller ships, 165 feet or less in length. The *Oceanographer* and *Discoverer* will join the fleet in 1965 with the *Rainier, Fairweather,* and *Mt. Mitchell* to follow. Although units of the fleet, with the notable exception of the ships *Surveyor, Peirce,* and *Whiting,* are now many years old, the ships' equipment has continuously been updated and is modern in all respects. The major ships have been outfitted with the most modern of precise positioning systems such as loran-C, Raydist, Hi-Fix, and with the latest developments in depth sounding and recording instruments, towed magnetometers, and other geophysical and oceanographic equipment. In recent years the operational assignments have included oceanographic studies as well as hydrographic work. Laboratory spaces have been outfitted and accommodations provided for the scientific personnel required. The fleet is supported by a substantial number of hydrographic launches ranging in length up to 36 feet. These launches, carried aboard the larger ships, are used for sounding operations where depth of water prohibits use of the mother ship, and for supplying shore camps in remote areas. Precise positioning and sounding gear are also provided in the launches.

The *Surveyor,* a 292-foot, 3,150-ton ship was added to the fleet in 1960. Completely air conditioned, equipped with the most modern gear for both hydrographic and oceanographic surveys, the *Surveyor* can cruise for 12,800 nautical miles at a standard speed of 15 knots. Accommodations are provided for a complement of 127 persons. Laboratories and plotting rooms make processing of collected data routine while underway. Deep-sea anchoring equipment makes possible fixed-position studies, coring, and dredging in the greatest depths of the ocean. Gravity meters, magnetometers, deep-sea cameras, and other sophisticated instruments are provided for a variety of studies.

The *Peirce* and the *Whiting,* two new hydrographic survey ships, joined the fleet in 1963. Identical in construction, they are used in both hydrographic and oceanographic work along the Atlantic coast of the United States and in the Gulf of Mexico. They have an overall length of 162 feet 7 inches, beam of 33 feet, and displacement under full load of 760.1 tons. The full load draft of the ships is 9 feet 6 inches. The steel hulls are ice strengthened to permit use of the ships in Alaska and in the ice-covered waters of the Arctic. They are outfitted with precise electronic positioning systems, sonic depth recorders, and complete electronic navigational and radio communications equipment. Each ship carries a complement of 6 officers and 30 crewmembers.

New ships nearing completion, under construction, or in the contract stage will extend materially the capabilities of the Coast and Geodetic Survey to conduct hydrographic and oceanographic surveys. The program, scheduled for completion by 1969, includes vessels designed primarily for hydrographic surveys. They are:

The *Fairweather* and *Rainier,* with a designed sea speed of 14½ knots, will be 220 feet in length, with a 42-foot beam and a 13-foot draft. Both will have accommodations for 80, including officers, scientists, and crew.

The *Mt. Mitchell,* of similar design will be 231 feet long.

The *McArthur* and *Davidson* will be 175 feet long, with a 38-foot beam and 11½-foot draft, and a designed sea speed of 13½ knots. Each will have a complement of 36, consisting of officers and crew.

The *Rude* and *Heck* will be 90 feet in length, with a 22-foot beam and 6-foot draft, and a designed sea speed of 11½ knots. They will have a complement of 10, including officers and crew.

The program also includes vessels designed specifically for oceanographic surveys. They are the *Oceanographer* and the *Discoverer,* 303 feet in length, a 52-foot beam, and an 18-foot draft, both with a designed sea speed of 16 knots. These ships are scheduled for commissioning in 1965, and will have accommodations for 116, including officers, scientific personnel, and crewmembers.

One vessel, 265-feet long, is being designed, with five other oceanographic survey ships in the planning stage.

To facilitate offshore surveys along bold and rugged coasts, with large and abrupt irregularities in depth, and many pinnacle-like rock masses, the Survey has developed equipment known as the wire drag. This method of determining depth has been of inestimable value in surveying in the Long Island Sound region, where huge boulders were deposited by the ice of the glacial period; in the Florida Keys, where large coral heads rise well above the surrounding bottom; and in parts of Alaska and the northern half of our New England coast, which are even more rugged, with great seamounts rising to within a few fathoms of the surface. Water areas have been dragged to depths as shallow as 6 feet for seaplane landing areas and as great as 350 feet for submarine trial courses.

The wire drag consists of a horizontal wire maintained at any desired depth below the surface by an arrangement of weights and adjustable upright cables which extend up to small buoys on the surface. The apparatus is towed by two vessels, one at each end. The horizontal wire will catch as the drag passes through the water and thus will indicate the location of any obstruction which extends above a plane at the depth determined by the

setting of the horizontal wire. The exact location of the obstruction having been thus found, the least depth on it can then be determined by echo sounder, leadline, or by divers.

Many improvements have been made in the wire drag since it was first introduced in 1904. The length of the wire drag in use today can be adjusted as necessary to cover a sweep up to 12,000 to 15,000 feet. As a result of successive improvements, the drag is now used to determine whether or not apparently clear water areas are free from obstruction; to discover and locate all obstructions in a shoal area; to determine the maximum safe depth of a channel; and to locate submerged wrecks. The effectiveness of the improved wire drag is indicated by the fact that in the tens of thousands of square miles of water area dragged by the Survey, more than 5,000 uncharted obstructions have been discovered.

Hydrographic Surveying

Hydrographic surveys which determine the depths of water and the character of the sea bottom were formerly obtained with the handlead, the deep-sea lead, or the pressure tube, and dangers were searched for with wire drag. During the past three or four decades considerable improvements have been made in hydrographic surveying methods with the development of echo-sounding equipment and improved methods of control. Accurate profiles are now obtained of the ocean floor that provide the cartographer with a wealth of information for detailed charting of submarine relief which is often characterized by intricate and distinctive patterns.

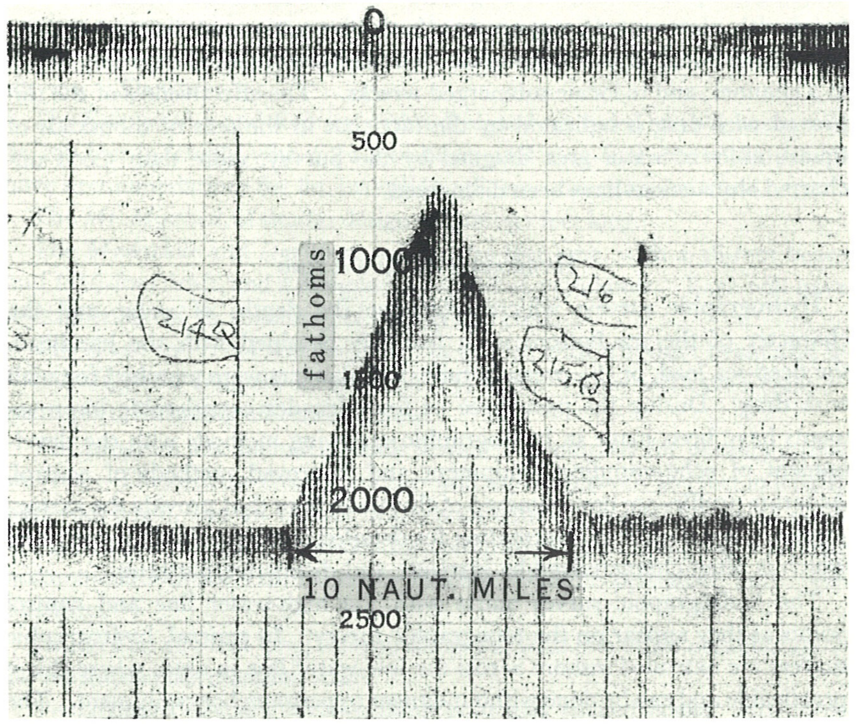
The hydrographic survey starts with the high-water line and control points as they appear on the topographic survey. In general, hydrographic surveys are extended inshore across the low-water line in areas where this is practicable and can be done without danger to personnel or equipment. The low-water line, one of the most important depth curves of a survey, is fully developed by our hydrographic surveys wherever tidal conditions permit.

Experience has shown that the most effective method of surveying an inshore area where the bottom slopes gradually is by means of a system of sounding lines parallel to the beach. Such lines can be run close to shore since the surveying launch is traversing a course parallel to the danger line rather than toward or away from it. Periods of high tide and calm weather afford the best conditions for inshore sounding and our operations are planned accordingly.

The hydrographer endeavors to obtain depths which will develop the area and delineate submarine relief in a thorough and economic manner by the methodical system of evenly spaced sounding lines. The first line of soundings is run as close to the high-water line as practicable. The lines of soundings nearest to shore are closely spaced with the two inshore lines spaced not more than 50 yards apart. The spacing of the system of lines is increased gradually until a maximum is reached between the two outermost lines.

Under many conditions a system of sounding lines parallel to the beach is impracticable. It is then necessary to use a system of evenly spaced sounding lines approximately normal or at an angle of 45° to the depth curves.

Soundings, the basic element of the hydrographic survey, are recorded on a work sheet by the hydrographer as the work progresses. The *boat sheet,* the designation given the work sheet, is used principally for plotting each



Fathogram of a volcanic-cone seamount rising 8,700 feet from depths of 2,100 fathoms or 12,600 feet.

position of the sounding vessel as the observations are made. In addition to the soundings, the boat sheet includes the locations and names of all control stations with descriptive notes added where necessary to identify a specific station. The boat sheet for an inshore hydrographic survey also contains the high-water line, the low-water line, the approximate limits of shoal areas, rocks, aids to navigation, and suspected dangers. Sextant cuts to locate a rock, breaker, hydrographic signal, or other features are carefully plotted on the boat sheet.

The *smooth sheet* is the name given to the hydrographic survey when reduced to plot form. It is essentially a record of the soundings taken during the field survey but contains other data necessary for a proper interpretation of our surveys. This projection was derived by Ferdinand R. Hassler, the graphic features, and control stations. The smooth sheet is plotted with the

utmost care and after being registered, verified, and reviewed in our Washington office it becomes the official permanent record of that particular survey. It is as complete for the water area as it is practicable to make it, and subsequent reference to the original sounding records is rarely necessary.

The polyconic projection has been adopted on which to plot the result of our surveys. This projection was derived by Ferdinand R. Hassler, the first Superintendent of the Coast Survey. It is especially adaptable for surveys of comparatively small areas such as those covered by hydrographic and topographic surveys. This is true because it effects a satisfactory compromise with all the most desirable properties of map projections, because of its ease of construction, and because a general table for its use has been calculated for the entire spheroid (C. & G.S. Special Publication No. 5, *Tables for a Polyconic Projection of Maps and Lengths of Terrestrial Arcs of Meridian and Parallels*).

In an effort to lift some of the burden of verification, review, and smooth plotting from the cartographer, an automatic data-recording system and a smooth-sheet plotter have been developed. As a first step a survey ship is equipped with data-acquisition equipment that records and stores all data needed to accomplish a hydrographic survey in a form acceptable to a computer. After processing the data, the computer produces programed directions for control of the automatic plotter. Both computer and plotter are to be shore based and will process all of the automatically obtained data.

Echo Sounding.—One of the oldest electronic surveying instruments is that employing echo sounding to determine the depth of water under the vessel. This method is now used almost exclusively in the hydrographic work of the Coast and Geodetic Survey. With this equipment, soundings can be obtained, in a second or two, in depths of as much as a mile. Thousands of soundings are now being obtained in areas where formerly only a few scattered ones were economically feasible. The original equipment depended upon audio and visual methods, whereas, practically all instruments now in use are of the recording type. The recorders connected with the sonic sounding devices provide a continuous profile of the ocean floor showing the ridges and depressions on a permanent visual graph.

The principle of echo sounding is the sending out of a sound impulse from the transducer in the hull of the ship, which on reflection from the ocean floor is picked up by this same unit and amplified so that it will make a permanent mark on a graphic record. The result of many consecutive soundings is to produce a profile of the ocean floor on the graph. Depths of water are measured accurately by measuring the small intervals of time required for the sound to make the round trip to ocean bottom. Although round-trip times are measured, the recording mechanism converts these times to depths of water.

Echo-sounding instruments may be divided into two classes, those for relatively shallow waters, such as obtained within a few miles of the shore, and those which will record depths in very deep water. Most of the smaller or shoal-water instruments are portable and may be used in launches as small as 25 feet in length. Portable echo sounders are used in the surveying of harbors, bays, rivers, and inshore areas along our coasts. This type of equipment is also installed in larger survey vessels for work in waters which are relatively shoal, yet extend many miles offshore, as in the case of the Gulf of Mexico where depths of only 100 fathoms exist 100 miles offshore. Fathograms recorded by these instruments can be read to 0.1 foot if desired.

Most types of deepwater echo sounders used in the larger ships will record the profile of the bottom in depths ranging from a few fathoms to those exceeding 4,000 fathoms (or 4½ miles). These recordings are made with a reading error of less than 10 fathoms in maximum depths and ranging to about 2 feet in the shoal areas. The larger ships are equipped with both a shoal-water and a deepwater echo sounder so that all conditions of depth may be examined.

A narrow-beam stabilized transducer for deepwater sounding is being developed. Because the narrow beam will result in a relatively small sound-reflecting area directly beneath the vessel, spurious bottom echoes should be reduced, thus improving the resolution of bottom features.

Many submerged features of interest have been found by using echo-sounding methods. Mountain peaks rising to heights of 10,000 feet or more have been found in ocean depths of 12,000 or 18,000 feet. Great trenches have been found along the continental shelf which drop to depths of more than 4,000 fathoms from a surrounding general-level bottom not much deeper than 2,000 fathoms. By means of echo-sounding instruments, intensive surveys have been made of vast areas along the coasts of the United States, including Alaska.

Hydrography accomplished annually averages more than 90,000 miles of sounding lines over areas totaling 50,000 to 75,000 square miles. In addition, about 200 square miles of water areas are wire dragged each year.

Control of Hydrographic Surveys.—The methods usually used to control hydrographic surveys depend on the distance from land and the depth of water. Where the survey vessel is close to shore, its position or the position of the sounding is obtained from control stations on shore. The usual method of fixing hydrographic surveys within sight of land is by sextant three-point fix which is almost universally followed for position fixing.

Beyond the limits of shore objects and where the use of three-point fix control is impracticable or unwarranted, a number of methods of control have been used in the past. Radio Acoustic Ranging (R.A.R.), including the radio-sono buoy, was a method developed by the Survey after World War I for offshore hydrographic surveying. By this method the position of the survey ship was determined from two or more previously located control stations by exploding a small bomb in the water near the ship and measuring the interval of time required for the sound to travel to each station. The explosion of the bomb and the radio signals that were transmitted automatically from the control stations were recorded on a chronograph carried aboard ship. The distances from the survey ship to the control stations were determined by measuring the time for the transmission of the underwater sound impulse, and the ship's position was thus determined.

The application of these scientific principles resulted in the extension of hydrographic surveying to considerable distances offshore with increased accuracy. This method was hailed as a great achievement and an enormous area was surveyed using the system. However, R.A.R. had several inherent disadvantages, none of which was completely overcome. World War II brought forth several new navigational methods which have made possible great improvements in our system of controlling surveys. As a result of these developments, Radio Acoustic Ranging has been replaced in the hydrographic operations of the Survey.

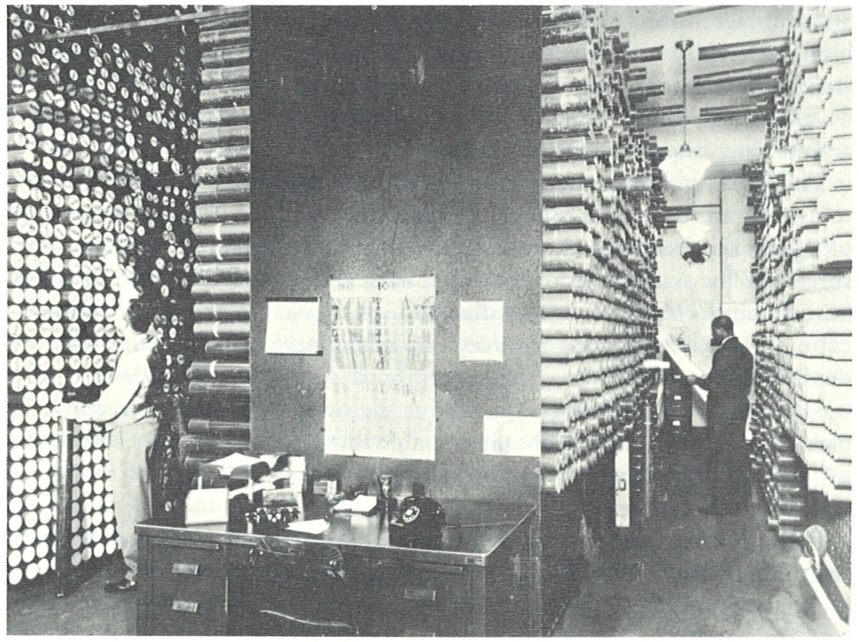
The Coast and Geodetic Survey was the first agency in the United States to use shoran for control of hydrographic surveys. The very great accuracy of the shoran fix has made it an essential control method for hydrographic surveys. The system was first tested in 1945 aboard the Coast and Geodetic Survey ship *Explorer* in the Aleutian Islands, Alaska, to determine its application in precisely locating a survey ship while traversing back and forth on depth-finding operations. The tests proved successful and shoran is now used on all the Alaskan survey vessels as the standard method for ship control. Vessels controlled by shoran are able to take soundings day and night, in fog and clear weather, continuously knowing the location of the vessel within an area of uncertainty of about 20 feet.

Shoran equipment is a special type of radar system designed and built for the particular purpose of controlling the position of an aircraft during a bombing mission. The fact that the equipment was designed to be used in, and transported by, aircraft is reflected in the general design of all components, including the power sources. The variation of our equipment from the original design is in the modification of the standard airborne equipment to serve as the beacon at the fixed control stations ashore.

Shoran as a line-of-sight method is limited to distances of 50 to 70 miles. While very accurate in its determination of a position, the system provides a relatively small service area, especially when equipments are installed at low elevations. An improved method of control was offered by the loran system which utilizes low-frequency radio impulses for transmission. Therefore an adaptation of loran is not limited by the line-of-sight range, as is the case with the high-frequency pulses of shoran. By combining the frequency and modulation of loran with the distance-measuring features of shoran, the Survey built the Electronic Position Indicator (E.P.I.). The principle of position fixing with E.P.I. is essentially the same as shoran with a greatly increased service area.

Field tests of the first E.P.I. instruments were made during the summer of 1945. The tests were sufficiently gratifying to warrant further research and development in the system. The following months were spent in further design and engineering, and the equipment now known as the Mark III, Model 2, was developed. Accuracies from 250 to 500 feet were obtained at ranges up to 400 miles. As the system required skilled operators on both the ship and ground stations, and due to the fact that errors could easily develop in the system, it is now considered obsolete.

Raydist type DM is now being used on several ships. The system requires two ground stations with a radio path between them and a total of four



Fireproof vault containing all original hydrographic and topographic, including photogrammetric, surveys.

radiofrequencies. This is a phase system and repeats itself every half wavelength at about 3000 kilocycles, or about 150 feet. Mechanical counters are used to totalize the lanes or area covered. These counters must be set at a known point at the beginning of the day's operations. While surveying, if the count is lost the ship must proceed to a known point in order to reset the counters. Accuracies of this system are in the order of 15 to 30 feet at its normal maximum range of about 150 miles.

Another system that is coming into common use is the Decca Hi-Fix. Like Raydist it is a phase system, but can easily be used either as a range-range or hyperbolic system. When used as a range-range system there is no radio link between the two ground stations. Only one radiofrequency is used at the ship and ground stations on a once-per-second sampling time shared basis. The frequency used is in the vicinity of 1700 kilocycles per second and therefore lane widths are in the order of 300 feet. The accuracies and ranges are about the same as Raydist.

For the greater ranges where coverage is available, loran-C is used. Loran-C is a hyperbolic system using a pulse and phase combination operating on a frequency of 100 kilocycles. The pulse-rise time is used to delineate the third radiofrequency cycle. On this cycle a phase match is made between the master and slaves in the hyperbolic chain. Some users apply a rule-of-thumb accuracy of 1,000 feet in 1,000 miles, or 100 feet in 100 miles. The maximum range for ground-wave coverage is about 1,250 miles.

Tide and Current Surveys

Observations and investigations of tide and currents are carried on by the Coast and Geodetic Survey to provide basic data for the surveying activities of the Bureau as well as to supply essential information for safeguarding maritime commerce, for aiding engineering projects associated with commercial and industrial development and protection of coastal property, as well as for various scientific, legal, recreational, and defense purposes.

For nautical chart production, soundings taken during hydrographic surveys must be adjusted for the height of the tide, so that the chart will show all depths referred to the same low-water datum. In photogrammetric surveys of our coastline, the aerial photographs must be correlated with the stage of the tide at the time of photography so that the high-water line and the low-water line can be accurately delineated from the photographs. In geodetic control surveys the sea-level datum used in the network of leveling is determined from observations at selected control tide stations located along our coasts.

Advance data relative to the rise and fall of the tide and the accompanying ebb and flow of the current are important aids to marine navigation. Such information is made available through the publication of annual tide and tidal current tables, and tidal current charts. Further dissemination of the information is obtained through the tidal predictions supplied by the Bureau to newspapers, radio stations, and private publishers of almanacs and calendars.

The daily predictions published in the tide and tidal current tables are calculated by a tide-predicting machine which was designed and constructed by the Coast and Geodetic Survey. It is about 11 feet long, 2 feet wide, 6 feet high, and weighs a little over a ton. This machine traces a continuous curve showing the variation of the tide or current, hour by hour, throughout the year, indicates by dials the time and height of each high and low water, or the time of each slack water, and the time and velocity of each strength of current that will occur every day of the year, and automatically types the predictions in the formats of the tide and tidal current tables, thus permitting direct reproduction by offset printing.

In the commercial and industrial development of coastal property, information on tides and currents is needed for the location or design of piers, bridges, and plant installation; for offshore oil production projects; and for the solution of problems of sewage disposal and water pollution.

Authentic tide-gage records obtained by the Bureau also are required for investigations, and actions associated with litigations, insurance, warnings, and protective measures related to extreme water levels caused by hurricanes.

These principal uses are supplemented by an increasing demand for tide and tidal current data for collateral uses, such as fisheries, sports and recreational activities, and for investigations of slow changes taking place in the relation of land to sea.

The tidal program of the Bureau includes the operation of a system of control tide stations located along our coasts and on certain islands. The basic data from these tide stations are supplemented by short-period observations from stations occupied during hydrographic surveys. A system of tidal bench marks is established by the Survey at each tide station to provide permanent reference points for the observed heights of the tide and the tidal datum planes determined therefrom.

Observations of the temperature and density of sea water are taken at most of the tide stations maintained by the Bureau as well as at a number of other locations. The data derived from these observations supply useful information to the shipping and fishing industries, to industrial plants using salt water, and to various scientific organizations.

Comprehensive tidal current surveys are carried out by the Bureau to provide detailed information on the circulation of tidal waters in important harbors and waterways. Basic data are obtained by the use of the Roberts Radio Current Meter which was designed by members of the Survey. Recently techniques have been developed in the Bureau to secure additional current information by means of photogrammetry. During such a survey, the body of water is seeded with targets for at least one ebb and flood cycle when the current is near its maximum velocity. The movement of the targets on successive photographs provides additional information as to the velocity and direction of the current. This method provides detailed information for the tidal current charts and circulatory studies which would be impracticable and uneconomical to obtain by standard methods.

Geodetic Surveying

The Coast and Geodetic Survey, as the name indicates, is the agency of the U.S. Government responsible for geodetic control surveys. Originally our geodetic surveys were made for the control of hydrographic and topographic surveys of the coast and to provide a proper base for the nautical charts. By congressional action in 1871, these activities were expanded to furnish basic control for the interior of the country, including geodetic connections between the Atlantic, Gulf, and Pacific coasts of the United States.

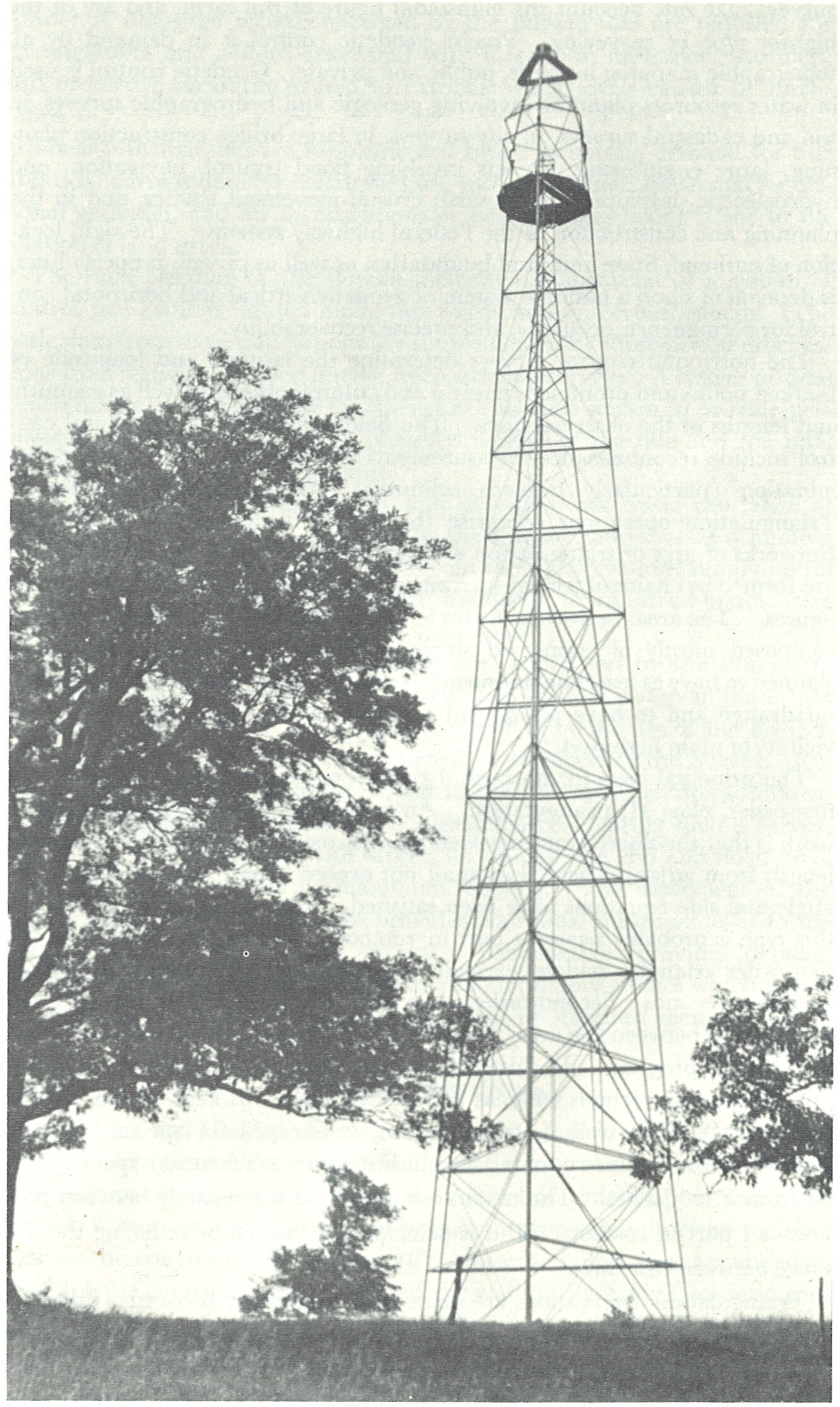
The geodetic work of the Coast and Geodetic Survey consists of the field surveys and office processing necessary for the determination of points in the basic national networks of horizontal control and vertical control, and also includes gravity and geodetic-astronomic determinations. These geodetic

surveys take into account the ellipsoidal figure of the earth, and are of the highest type of surveying. Precise geodetic control is in demand by all topographic mapping interests, public and private. Geodetic control is used in water resources planning involving geologic and hydrographic surveys, in soil and cadastral surveys, in city surveys, in large bridge construction planning, large engineering projects involving flood control, navigation, and hydroelectric developments, in earth crustal-movement studies, and in the planning and construction of the Federal highway systems. The rigid location of national, State and local boundaries, as well as private property lines, is dependent upon a national system of geodetic vertical and horizontal control for permanence, accuracy, and precise recoverability.

The horizontal control surveys determine the latitude and longitude of marked points and prominent natural and cultural objects as well as azimuths and lengths of the observed lines. The field operations for horizontal control include reconnaissance, measurements of base lines, astronomic determination (particularly Laplace azimuths), triangulation, and traverse. Triangulation operations comprise the greater portion of the fieldwork. Networks of arcs of triangulation extend over the United States. The arcs are formed by chains of triangles arranged in quadrilaterals and central-point figures. The areas between the arcs are being filled in with a continuous net composed mostly of connected single triangles. For basic control, it is planned to have at least one station established in each 7½-minute geographic quadrange and to have permanent points at 4- to 5-mile intervals in the vicinity of main highways.

The principal basis for horizontal control surveys is comprised of arcs of first-order, class II, triangulation. An important criterion of this class of work is that the discrepancy between a measured base line and its computed length from adjacent base lines shall not exceed 1 part in 50,000 after the angle and side equations have been satisfied. The average discrepancy for this type is probably nearer 1 part in 100,000. The average closure of the first-order triangles seldom exceeds 1 second and the maximum seldom exceeds 3 seconds. Second-order, class I, triangulation, which is used to fill in the areas between the arcs, is observed with first-order instruments under a first-order program. In this class of work, however, the maximum allowable closure is 5 seconds whereas the average closure is kept within 1.5 seconds. First-order, class I, triangulation, is reserved for special purposes such as control for metropolitan and industrial areas where the spacing may be from 2 to 5 miles. The maximum allowable discrepancy between base lines is 1 part in 100,000. This is principally achieved by reducing the distance between base lines.

Triangulation observations are made with high-grade first-order direction theodolites, usually at night, on signal lamp targets. In many areas of the country, triangulation surveys have been greatly expedited by using Bilby steel towers. These are double towers formed by two demountable portable steel tripods. The inner tripod supports the instrument independently,



Bilby triangulation tower.

and the outer tripod supports the observing party, tent, signal lamps, and other gear. These towers can be built, in a few hours, to heights of from 37 to 116 feet. The components are steel bars and rods fastened by nuts and bolts. They can be taken apart in even less time, and then hauled by truck to the next site. The towers can be erected and taken apart many times.

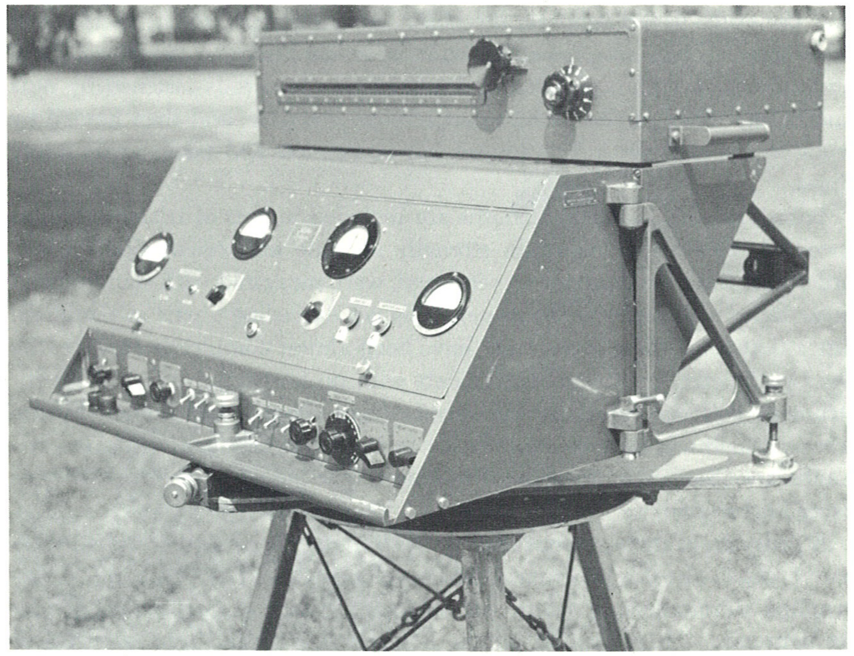
Base lines and Laplace azimuths are included in arcs of triangulation at specified intervals to maintain strength in scale and orientation. First-order base lines, up to about 10 years ago, were measured with standardized invar tapes with probable errors generally not exceeding 1 part in 1 million. Since that time, these invar tapes have been almost completely replaced by the Geodimeter for base measurements with no loss in accuracy. This instrument uses very precisely the speed of light and is not limited by the terrain which was an important factor in the taping method. Laplace azimuths are observed with methods to ensure that the probable error will not exceed 0.3 second.

A program of three-dimensional satellite triangulation is presently underway (1964). In this program passive satellites of the Echo type are photographed simultaneously from two or more ground points against a star background. These ground points, or camera stations, form triangles of about 800 or 900 miles on the side and it is planned to extend this work through the lower 48 States to Alaska and Canada. Observations have been made at Bermuda and Antigua at the request of the U.S. Air Force to connect these points to the North American Datum of 1927.

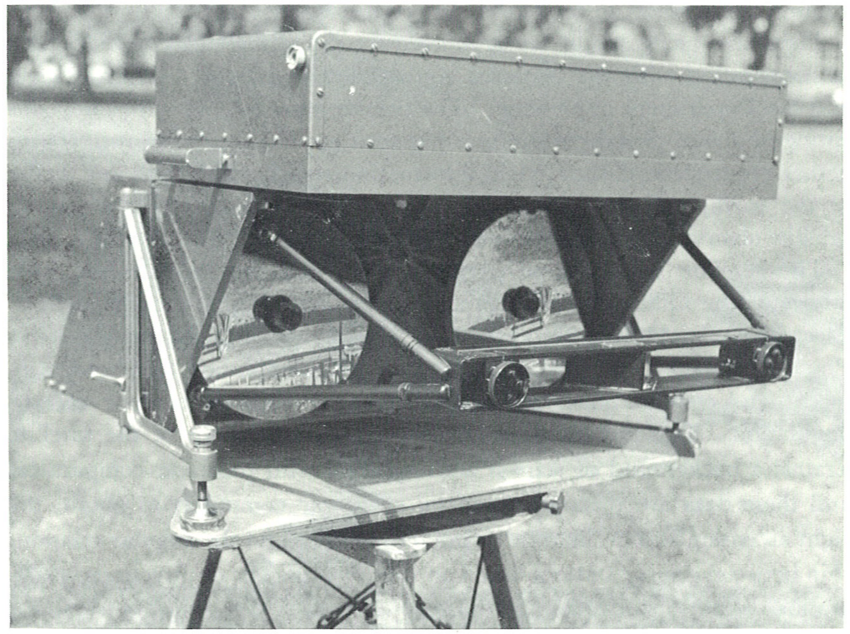
Plans are being made for a worldwide satellite triangulation project in cooperation with the National Aeronautics and Space Administration and the Department of Defense. The resulting triangulation scheme, consisting of about 36 stations uniformly spaced around the world, will tie together all geodetic datums, yield information regarding the size and shape of the earth, and provide an accurate geometric framework for future satellite observations for geophysical purposes.

The satellite triangulation program is carried out through the joint efforts of the Office of Research and Development, and the Divisions of Electronic Computing, Geodesy, and Photogrammetry in the Office of Physical Sciences. Satellite triangulation is accomplished by photogrammetric and computational procedures similar to those of analytic aerotriangulation. The measurement of glass-plate photographs of the satellite against a background of stars is accomplished with precision comparators and these data are then processed on electronic computers to obtain the right ascension and declination of satellite images, and the angular relationship between ground stations based on intersecting rays, or directions, at the satellite.

All points in the continental geodetic network of horizontal control are referred to the same datum (North American Datum of 1927) and are therefore correctly related in position with respect to each other, regardless



Geodimeter, front or operating side.



Geodimeter, back or lens and mirror side.

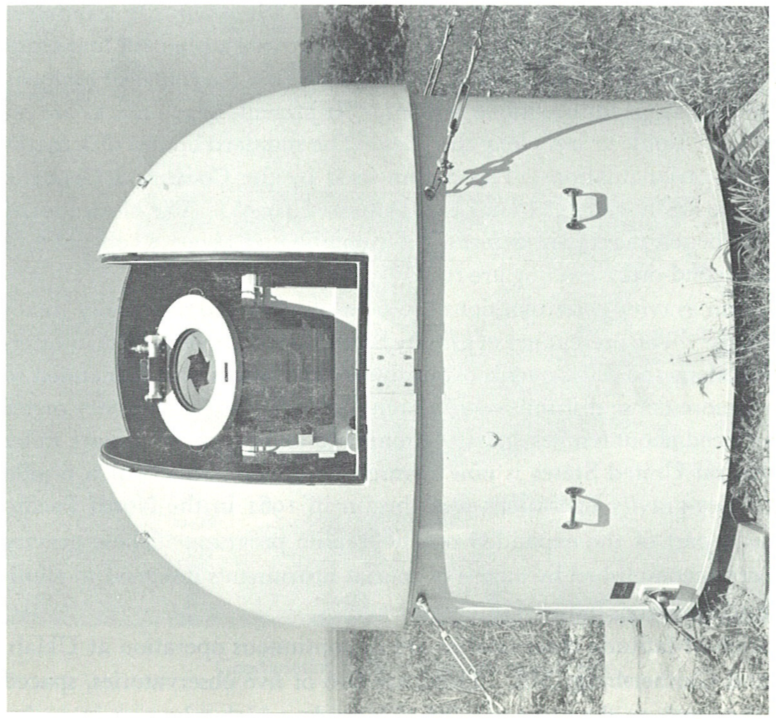
of their distance apart. The Clarke Spheroid of 1866 is the basis of computation.

Descriptions of stations and geographic positions are published for public use. The plane-coordinate positions on the adopted State Plane-Coordinate system are also published for all adjusted positions. The geographic positions have been determined for approximately 170,000 stations in the United States, including Alaska, consisting of marked or monumented points and prominent objects. Stations are marked by bronze disks set in concrete monuments, bedrock, structures, etc. The present standard complete marking of a triangulation station consists of a station (center) mark, an underground mark—3 feet or more below the center where practicable, two or more reference marks, and an azimuth mark visible from the ground and usually at least one-quarter mile distant. During an average year's work about 50,000 square miles of triangulation are completed, and about 3,000 geographic positions are established. About 25 base lines, average length about 8 miles, are measured each year.

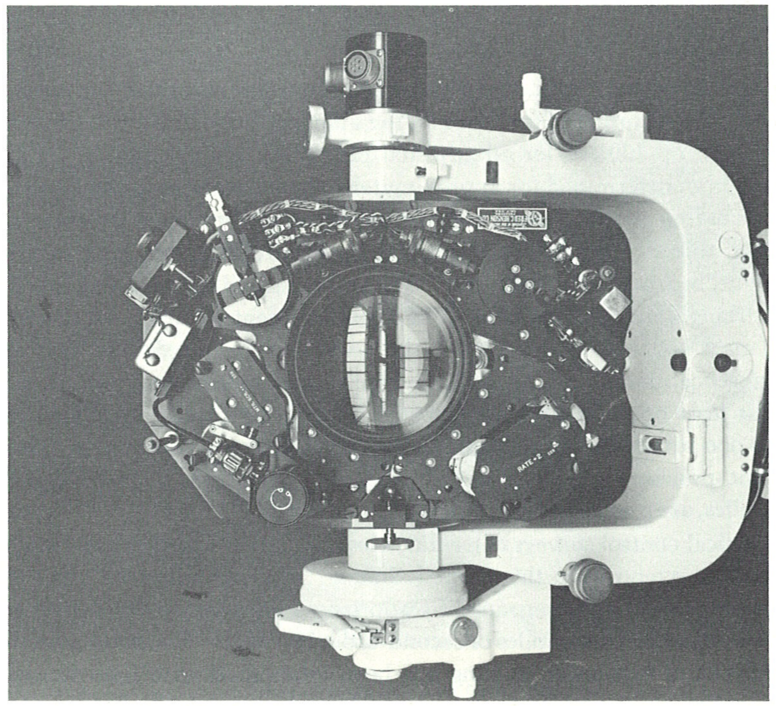
The vertical control surveys determine elevations of the network of bench marks which extend over the United States. The elevations of 439,000 bench marks have been determined by approximately 192,000 miles of first-order leveling and 291,000 miles of second-order leveling. The main nationwide network of first-order leveling has been established with lines spaced 60 to 100 miles apart. With the exception of necessary releveling for reasons of recovery, and to bring vertical control established prior to 1916 up to present standards, the main network is complete. Second-order leveling is being established within the first-order loops to provide a planned line-spacing of approximately 6 miles. Most of the lines follow the routes of highway and railroad systems for economic reasons. At present, bench marks are set at intervals of 1 mile or less along the lines. The standard bronze disk marks are set as in triangulation. The datum used by the Coast and Geodetic Survey is the mean sea level (Sea Level Datum of 1929). The elevations of over 8,000 bench marks are determined annually and about 7,500 miles of first- and second-order leveling are run.

Pendulum gravity determinations are being superseded by gravity meter observations. The present net of gravity base stations provides data at intervals of less than 100 miles over most of the United States. It is planned to provide a more dense distribution of gravity information with gravity meter stations spaced about 6 miles apart. An area of about 900,000 square miles in the central United States is now covered by gravity surveys at a 6-mile spacing. Sea-gravity operations were begun in 1961 in the North Pacific Ocean as a part of the expanded oceanographic program. These gravity surveys are accomplished by means of special instruments designed to eliminate the accelerations induced by ocean waves.

Variation-of-latitude observatories are in continuous operation at Ukiah, Calif., and Gaithersburg, Md. These are two of five observatories, spaced around the earth on the same parallel of latitude, which take part in an in-



Astrodome designed specially for the BC–4 satellite tracking camera.



BC–4 camera showing the high precision gearing system required for disk shutter operation.

ternational program of observations to detect the movements of the axis of rotation within the body of the earth.

In addition to astronomic azimuth and longitude observations which are made at the numerous Laplace stations of the triangulation schemes, latitude observations are usually made at the same time for use in figure-of-the-earth studies. Also, networks of second-order astronomic positions are being established to provide more detailed information on the undulations of the geoid. Nearly 2,000 astronomic stations have been observed.

Special geodetic work carried on in the Washington headquarters includes the adjustment of foreign surveys; the preparation of tables of map projections, grid intersections, and loran data; the determination of intercontinental distances requiring geodetic evaluation of the relative positioning of the world datums and the size and shape of the earth; the preparation of the State Plane Coordinates; the investigations and computations contributing to scientific and technical studies involving crustal movements particularly in earthquake and subsidence areas; investigations of the effect of irregularities of the earth's gravity field on the operation of inertial navigation and guidance devices; evaluating suggested improvements to operations; and coordinating all geodetic operations with the current needs of other agencies and organizations engaged in mapping and engineering endeavors.

Topographic Surveying

Large-scale surveys of the topography of the coastline and the immediately adjacent land areas are essential to the production and maintenance of nautical charts; consequently, since its inception, the Coast and Geodetic Survey has been engaged in mapping the coastline. For the most part, the coastal mapping executed by the Survey is limited to terrain features adjacent to the shoreline and other land features that are essential for control for hydrographic surveys and which are also necessarily shown on nautical charts as aids in alongshore navigation. With the advent of radar navigation, landforms are becoming increasingly important to the navigator. In recent years, large scale mapping, particularly of airports, has been undertaken for the production and maintenance of certain aeronautical charts and for the production and maintenance of a series of Airport Obstruction Plans used by the Federal Aviation Agency and the air carriers for determining the maximum safe weight of aircraft for landing and takeoff in reference to existing obstructions and other factors.

Until the advent of aerial photography, ground-planetable surveying was used exclusively by the Coast and Geodetic Survey as the method of making topographic surveys. Ground topographic methods have given way to the more economical and more expeditious method of photogrammetry which was first used in surveys made in connection with the Alaska-Canada boundary in the 1890's. At that time photographs were taken from the ground at points of known position and were used in lieu of planetable observations to determine the positions of minor points and other details. Although the method (terrestrial photogrammetry) was used with considerable success, it was not generally adopted and photogrammetry was not used again until 1918 when some aerial photographs became available for experimental surveys.

The method of aerial photography and photogrammetry, more complete in coverage and less tedious in application, soon demonstrated its superiority over ground-planetable surveying, and since 1928 has developed rapidly to the point where it is now used for all our mapping for the production and maintenance of nautical charts. This method provides the maps of the coastline, that is the land information, required for the construction and maintenance of nautical charts. Large-scale shoreline maps are made prior to hydrographic surveys to show the shoreline in detail, including slightly submerged features close to the land, and to provide control stations for hydrography. Photogrammetric mapping of the coastline is also done, by means of stereoscopic instruments, directly onto the nautical chart drawings, at the publication scale of the chart, when larger-scale drawings are not required for hydrography or other purposes. Landmarks and aids to navigation are located photogrammetrically.

A considerable effort is devoted to monitoring the coastline and correcting chart drawings directly from new aerial photography by means of stereoscopic plotting instruments.

Repeat aerial photography and repeat surveys are essential for the up-to-date maintenance of nautical charts. Consequently, the Bureau files of aerial photography and the Bureau archives of survey records, including the planetable surveys of the coastline made prior to photogrammetry, contain a unique record of coastal changes over a period of 130 years. Certified copies of these records are often used in the courts for cases involving the shoreline as a property boundary.

Photogrammetric Operations

Photogrammetry (meaning to obtain reliable measurements by means of photography) is used in the Coast and Geodetic Survey for making detailed surveys of land areas and for obtaining a variety of data required for Bureau programs and studies. This work includes the operation of aircraft for aerial photography, terrestrial photography such as that taken for satellite triangulation, and deep-sea photography; field surveys to establish supplemental ground control for mapping and to obtain information not recorded on photography; photogrammetric aerotriangulation for the control of mapping and for positioning specific features or objects such as landmarks for charts and aids to navigation; photogrammetric measurements and computations for satellite triangulation; stereoscopic instrument compilation of manuscript maps; the distribution of aerial photographs and survey data; and research and development for improving the quality and precision of cameras, film, laboratory processing, and photogrammetric measurements.

Two aircraft, one fitted for simultaneous photography with two cameras, are used to take panchromatic, infrared, and color photography with wide-angle and superwide-angle single lens precision mapping cameras. Most of the photography is taken on film, but glass plates are also used for the most precise work. Most of the aerial photography covers two primary areas of Coast and Geodetic Survey interest: the coastline of the United States, including bays and harbors, and commercial airports of the United States. The photography is repeated at regular intervals for the up-to-date maintenance of nautical charts and of airport obstruction plans. Consequently, the Bureau has a unique photographic record of the coastline and of civil airports. Practically all of this photography, including color photography, is made available to the public.

Observations for three-dimensional satellite triangulation are made by photographing passive satellites, such as *Echo I* and *Echo II*, against a background of stars using precision glass-plate terrestrial cameras with electronic timing devices so that exposures can be timed with an accuracy of about 150 microseconds. Deep-sea photography is taken with a camera system composed of two 35 mm. cameras, without shutters, spaced at either end of a short base. Exposure is made with high-intensity lights timed to flash at 14-second intervals. Satisfactory photographs of the ocean floor have been obtained at depths as great as 23,200 feet.

Photogrammetric field surveys provide the connection between the aerotriangulation and the basic geodetic network of control stations by making supplemental horizontal and vertical ground control surveys by means of triangulation, traverse, and leveling, and by identifying the ground control on the aerial photographs. Ground control stations are identified on the photographs by one of two methods: targets may be placed on the control stations prior to aerial photography which show on this photography as small dots or crosses, or if identification is done after the aerial photography, the field parties select, and determine the positions or elevations of natural or cultural features visible on the photographs.

Photogrammetric field survey parties also provide position control and other support for inshore hydrography, make airport surveys, and obtain a variety of data not recorded on aerial photography.

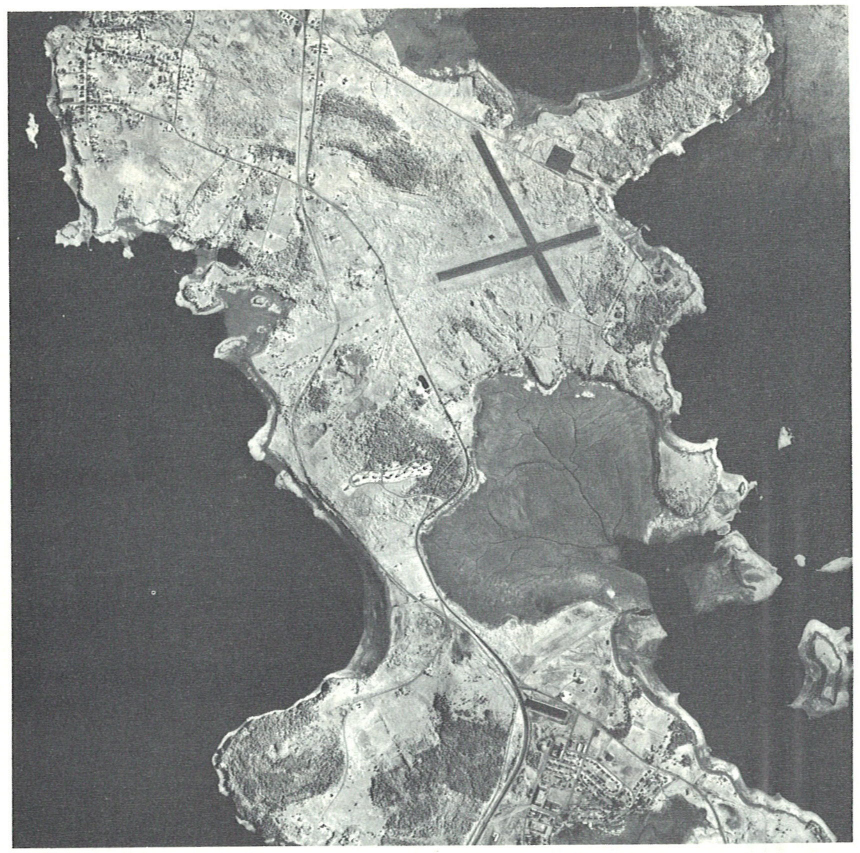
Aerotriangulation, as the name implies, is a method of triangulation by means of measurement on aerial photographs to determine the horizontal and vertical positions of terrain points. Aerotriangulation, in strips or blocks, starts with the rather widely spaced stations of the basic geodetic control network established by the geodetic surveys of the Bureau and determines the horizontal positions and elevations of additional terrain features at closer intervals for map compilation and other purposes.

In the Coast and Geodetic Survey, aerotriangulation is done with panchromatic, infrared, or color photography, by means of analog instruments such as the stereoplanigraph, and by means of the much more accurate analytic method. Strip aerotriangulation with the stereoplanigraph is adjusted to

Panchromatic photograph taken simultaneously with the infrared photograph on the opposite page.

the basic ground control by means of electronic computers. Photogrammetric measurements for analytic aerotriangulation are made with precision computers that are capable of measuring accuracies of about 0.001 millimeter, or 0.00004 inch. In the analytic system, the relative orientation of photographs to form models, the connection of adjacent models through a strip, and the adjustment of the strip to geodetic control are all performed by computation with electronic computers. The analytic method also provides for the adjustment of a block of several parallel strips of photographs to ground control by means of a large electronic computer.

Map and chart compilation, from aerial photography and control provided by aerotriangulation, is done with stereoscopic instruments. Color photography is used extensively because of its superior interpretability and the Bureau has a complete color laboratory for processing color film and for making all types of prints from that film. Infrared photography is also used for mapping in connection with nautical charts and is very effective for lo-



Infrared photograph taken at mean low tide for mapping the mean low-water contours.

cating an exact shoreline contour, such as the mean-low-tide line or the mean-high-tide line.

Photogrammetric surveys are made of common-carrier airports throughout the United States to prepare and maintain up-to-date the series of airport obstruction charts and turbine-data sheets prepared by the Coast and Geodetic Survey for the Federal Aviation Agency. This program also includes the positioning of aids to air navigation such as the several types of omnidirectional ranges that mark the national airways.

Photogrammetric operations in oceanography include the measurement of tidal currents, deep-sea stereoscopic photography for spot studies of the ocean floor, and various research and development studies.

Photogrammetric operations in geodesy include satellite triangulation, mentioned earlier, and research and development studies toward the application of analytic aerotriangulation to the measurement of crustal movement, to the breakdown of control for mapping, and so on.

Special photogrammetric surveys for other Bureau programs and for other agencies of Federal and State governments include aerial photography for the study of faulting and changes following earthquakes; boundary surveys; cadastral surveys; mapping with infrared photography; and advice and assistance in the application of photogrammetry to various surveying and mapping problems.

Magnetic Surveys

Man's knowledge of his environment on and about the earth moves forward with every unfolding phase of geophysical science, each new insight dovetailing with prior gains to support vital functions of technology and modern living.

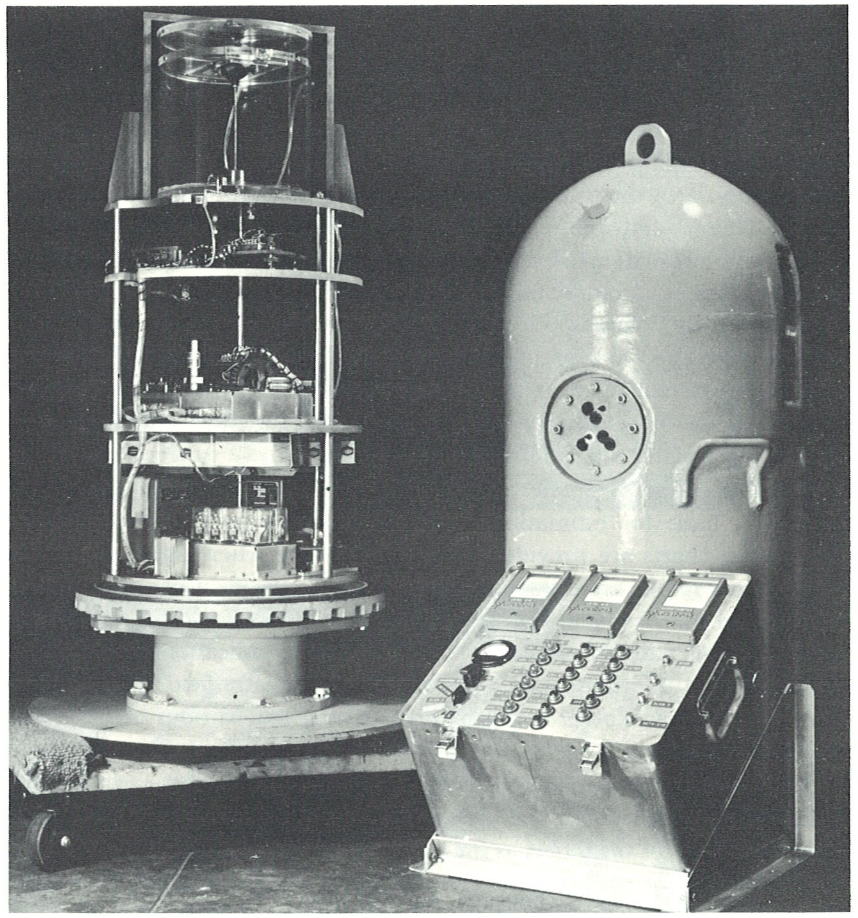
The responsibility for geomagnetic work in the United States and its possessions belongs to the Coast and Geodetic Survey as an outgrowth of its primary task of preparing charts for the navigation of vessels and aircraft. The user of the compass must depend on information which he cannot ordinarily determine for himself as to the amount that its indication departs from true north (the magnetic declination or variation). The compass has important collateral uses in land surveying and several other fields, but it is a basic tool in sea and air navigation; furthermore, the navigator must know to what extent his compass is affected by the iron in his ship. This is a difficult problem—to solve it we must know the dip and intensity of the earth's magnetic field.

All this is still but a small part of the present-day scope of geomagnetic studies. In geophysical exploration for mineral wealth, in the study of both the earth's deep interior and its upper atmosphere, in all forms of telecommunication, in cosmic-ray studies, in solar-activity investigations, and in the exciting new realm of space technology, the findings are profoundly dependent on data about the configuration and changes of the earth's magnetic field.

The planet earth undergoes a sporadic but never-ending barrage of radiation and plasma emitted by the sun. These emissions, impinging on and interacting with the earth's magnetic field and the upper atmosphere, give rise to vast electric currents and complex shells of streaming ionized gases characterized by potent radiations. Accompanying transient magnetic variations registered at magnetic observatories afford valuable clues to the conditions aloft and to the associated phenomena, which include auroral displays, ionospheric disruptions (radio fadeouts), air transport difficulties, and interference with geological prospecting operations and other technical works. The geomagnetic transient fluctuations are tangible and easily metered. Moreover, some of them appear to precede the other effects, generally giving this area of observation an important function as an alerting index respecting the others. For instance, the predictions of radio-wave propagation conditions by the National Bureau of Standards are strongly based on the indications of magnetic observatory instruments. The radiation belts that envelop the earth and present formidable hazards to space

exploration are controlled in their configuration and intensity by the magnetic field and by the same solar emissions that are reflected in the magnetic records.

Prior to 1850, Prof. Alexander D. Bache (the second Superintendent of the Coast Survey) personally engaged in and directed the initial geomag-



Elements of the underwater stabilized platform.

netic work of the Survey, including observations for magnetic declination, dip, and intensity. This work was pursuant to the original Hassler plan which prescribed that "magnetic bearings should be regularly observed at each principal station." These early observations were confined to the coastal regions, since they were intended to provide magnetic data for nautical charts. Later the work was extended to the interior of the country, and it was greatly expanded and intensified at the turn of the century. To meet the practical needs exemplified above, an effective and well-balanced program has been evolved, calling for long-range coordination of work over a vast area, and hence for the functioning of a technically qualified staff devoted to these activities.

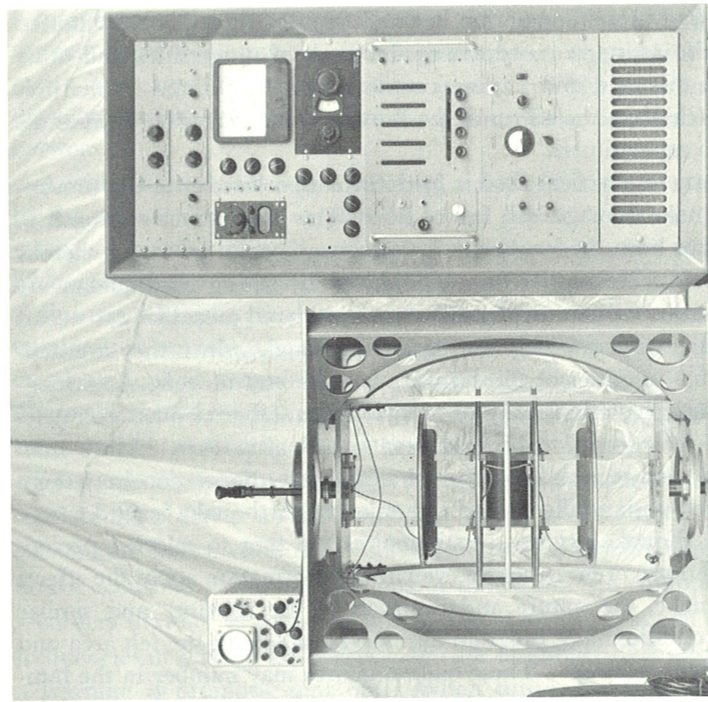
Magnetic observations have been made at many thousands of stations including nearly all of the more than 3,000 county seats in the United States. Magnetic observatories have been set up at some 40 places, and 14 of these are in current operation to record in detail all the fluctuations and gradual changes that are manifested in the magnetic field. The largest is a completely up-to-date establishment near Fredericksburg, Va., equipped with facilities for testing and calibrating geomagnetic instruments under simulated conditions of all parts of the globe, and with the most advanced instruments for keeping track of the fluctuations in the earth's field at the observatory. Of the other observatories, one is in Arizona, one in Hawaii, one in Guam, and one in Puerto Rico, while three are in Alaska. In Antarctica, installations at the South Pole, Byrd Station, and Eights Station are providing important data. The other three observatories are cooperative installations in Colorado, California, and Texas. The slower changes are further monitored at about 150 selected stations where "repeat" field observations are scheduled at about 5-year intervals. Detailed examination is made of the local patterns encountered at the compass testing platforms of airfields, safeguarding an important function.

The Coast and Geodetic Survey regularly issues magnetic charts that provide a basis for estimating magnetic elements in any given locality. Navigation charts are provided with specific data when issued or revised. Observatory results are disseminated in several ways, including prompt mail distribution and frequent journal publication of activity data and annual detailed publication of statistical results. Other publications are available giving general information about the earth's magnetic field, the effects of daily variation and other transient fluctuations, and various other aspects of geomagnetism.

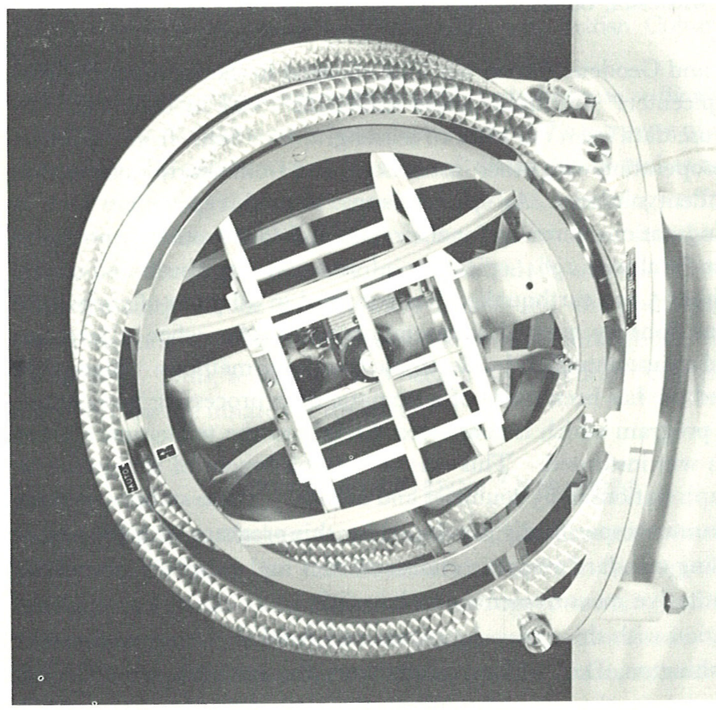
The study of the secular and other temporal changes of the earth's magnetic field is important to the preparation of valid magnetic charts of any substantial part of the globe, as for example the United States; but this can only be done correctly with access to worldwide data. The Coast and Geodetic Survey has long engaged in the international exchange and collection of geomagnetic data as formally recognized for the past 15 years in the legislation defining the Bureau's mission. More recently, this function has included the collection of microfilm archives of worldwide recordings from magnetic observatories, pursuant to the program of the International Geophysical Year of 1957–58 and subsequent sustained requirements of the geophysical community.

Seismological Surveys

In 1925, Congress designated the Coast and Geodetic Survey as the Government agency responsible for the study of seismology and the dissemination to the public of information derived from this study. Prior to this time,



Proton vector magnetometer by which magnetic standards are maintained through its routine use.



Sensing element and bias coil system of the automatic standard magnetic observatory.

seismographs had been in operation in the Bureau's magnetic observatories. The Survey also assists in coordinating the work of universities and other institutions in this field and serves as a clearinghouse for the results they obtain. In such ways, the efforts of the Bureau yield returns far beyond the level of its own expenditures.

The most urgent practical need is for information leading to the prevention of earthquake damage and loss of life. The most direct approach to this problem has been the strong-motion program, begun in 1932, whereby instruments that measure the forces produced by strong earthquakes are operated in localities where earthquakes are considered most likely to occur. These instruments operate only during an earthquake, since they are activated by the first motions of the tremor. At the end of 1963, 80 strong-motion seismograph stations were in service. A number of other countries have adopted strong-motion programs patterned after ours. More than 1,200 strong-motion records have been obtained and information from them has contributed substantially toward reduction of earthquake hazard.

After an earthquake occurs, questionnaires are sent to selected persons in the shaken area in order to collect eyewitness information about the effects of the earthquake, the nature and duration of the shaking, and similar details. The questionnaire program also serves to delimit the felt area and the various intensity levels. These questionnaires may number in the hundreds or thousands for a single earthquake, depending on the severity of the shock. In important earthquakes, trained personnel inspect the area and interview eyewitnesses, obtaining significant information that others might overlook.

The Coast and Geodetic Survey has long engaged in the location of earthquakes or "epicenters" and holds world leadership today in that field. In this work we use data from our own 10 seismograph stations, from 14 others operated in cooperation with other institutions, and from nearly 1,000 worldwide independent stations. As epicenters are located, reports are sent to the cooperating stations in return for their data and to any others who desire them. In the fiscal year 1964, epicenter information was distributed on the location of about 5,000 earthquakes that occurred in all parts of the world. This work was done by manual computation until 1960, when a program was developed to accomplish it by electronic computer methods. Since that time, increased use has been made of automatic data processing procedures.

In 1960, a program which is connected directly to the teleseismic studies of the Bureau was instituted. This was the establishment of a network of 125 seismograph stations in 65 countries and islands. These stations contain standard instruments specifically developed for this program with the objective of obtaining standard response characteristics and records from which reliable quantitative measurements can be made.

In conjunction with this network, a Data and Analysis Center was established in Washington, D.C. The records from the network are collected at this Center where they are photographed on 70-mm. film from which

a complete archives is being assembled. Copies made from this master file are sent upon request to research scientists around the world. An analysis group is engaged in research on basic seismic problems such as wave path, velocity, magnitude, and energy propagation, using data obtained from the network.

Another hazard, wherein seismology occupies a key position, is presented by the seismic sea wave or tsunami, often popularly referred to as a tidal wave. A number of such waves of potentially destructive magnitude have been generated in recent decades by strong North Pacific earthquakes. Following the destructive wave of April 1, 1946, the Survey organized, and continues to operate, a warning system involving the cooperation of seismograph stations at several Bureau observatories, surveillance reports of tide observers, special sea-wave warning devices, and an integrated communication network centering on the Honolulu Observatory. The seismograph stations are equipped with visual recorders and automatic alarm systems to alert the observer at any hour if an important earthquake occurs. By exchanging information the observers determine quickly where the earthquake occurred. The tide stations in the system are equipped with wave recorders that are so tuned as to sound an alarm in reaction to the special frequencies of seismic sea waves. In case of danger of a seismic sea wave, a warning is promptly sent out. When this system was established, the warned area consisted of the Hawaiian Islands. In March 1964, at the time of the Alaskan earthquake, the warned area consisted of the entire Pacific basin from Japan to Chile and from British Columbia to New Zealand.

This warning system has been possible only because sufficiently sensitive seismographs had previously been developed for the purposes of pure science; that is, for the detection and location of distant earthquakes and the study of the structure of the earth's interior. In fact, seismology affords the only available precision tool for delineating the structure of the inaccessible interior of the earth. This is accomplished in several ways, principally from the study of the speeds, wave forms, and energy content of elastic waves that originate from earthquakes and travel through the earth or along its surface. Thus, seismology has been aptly called an "eye through which one may view the innards of the earth."

Combined Surveying Operations

Surveying our Alaskan waters and adjacent coastal areas has been a pioneer undertaking by the Coast and Geodetic Survey. Surveying in Alaska is at best slow and difficult due to rugged terrain, bad weather, and foul inshore areas. Ice conditions and low temperatures add to the difficulties. To pursue this work successfully, special planning and coordination of surveying operations have been necessary. In surveying isolated regions under adverse conditions the method of combined surveys has been developed by which each ship operates as an expedition.

The modern surveying ship in use today carries equipment and trained personnel for accomplishing all operations incidental to completing surveys in areas far removed from home ports. Ship-based parties with personnel trained in making hydrographic, topographic, geodetic, and related surveys have been especially effective in conducting this work in Alaska. In recent years extensive operations have been carried on along the bleak and barren chain of Aleutian Islands which extend more than 900 miles in a southwesterly direction from the Alaska mainland. In addition to the execution of hydrographic surveys, members of the surveying ship are required to establish geodetic control, conduct topographic surveys for the location of signals for hydrographic control and the delineation of shoreline by planetable, make magnetic observations, and obtain tidal information through tide and current surveys. Also, aerial photographs are field inspected and necessary control points are identified and described. Thus combined surveying operations with ship-based parties have come into general use as the medium for conducting our Alaskan surveys.

Nautical and Aeronautical Charts

Growing waterborne commerce during colonial days created the need for nautical charts, for guiding the mariner safely and expeditiously into and out of coastal harbors. The need for similar charts for airborne commerce arose after World War I, with the ensuing development of aviation. The Coast and Geodetic Survey is responsible for the construction, publication, and maintenance of the nation's nautical and aeronautical charts.

For about 125 years the Coast and Geodetic Survey has published nautical charts of the United States, its territories and possessions. The first chart was an engraving on stone published in 1839 of Newark Harbor, but the early charts were produced mainly as copperplate engravings. The early engravings were characterized by elaborate titles and notes and engraved views of headlands, lighthouses, and harbor approaches. Lithographic methods were employed in reproducing our charts as early as 1897, and since 1905 copperplate engraving has been gradually discontinued until now all our charts are produced entirely by modern photolithographic methods.

The aeronautical charting program began with the passage of the Air Commerce Act of 1926. The first charts published were in strip form that followed the newly lighted airways between the major air terminals. These charts were soon followed by a series of 87 sectional aeronautical charts published for low-altitude contact flying throughout the United States.

Rapidly expanding maritime and air commerce, and developments in navigational aids and methods have increased manyfold the demand for new types of charts and modernization of existing ones, and military requirements have accelerated and magnified charting programs.

Nautical and aeronautical charts are printed in a modern humidity-controlled pressroom. The line of presses includes one 5-color and five 2-color offset presses, and one 1-color press capable of handling plates 47¼ by 60 inches. Many charts are run through the presses several times in order to print the multiple colors required in accentuating various chart detail. As many as 12 printing plates are used for 1 aeronautical chart series. About 35 million copies of nautical and aeronautical charts, and related printings are published yearly.

The hum of the presses is no greater than the activity which precedes press runs. An adjoining room houses the graining machines where the mechanical agitation of glass-graining marbles, sand, and chemically treated water prepare the surface of the aluminum printing plates for photolithographic processing. Nearby, motorized whirlers spread the photographic chemicals evenly over the plates; and in the same photographic room a row of large vacuum frames are busily transplanting images to the plates from the glass or plastic negatives. Preceding the contact between negatives and plates are the various photographic processes employing cameras as large as the 14½-ton, 50-inch precision camera used for the largest wet-plate negatives. The cameras and developing tanks are kept busy not only with lithographic copy, but also with making copy of the various materials required during compilation of the charts.

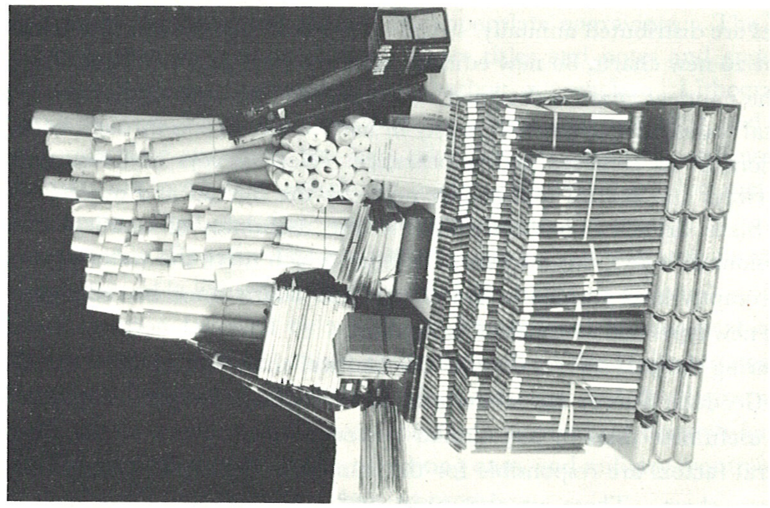
Nautical Chart Production.—Nautical charts are compiled principally from basic field surveys made by the Bureau, and they include all information essential for safe navigation. To meet the different navigational needs, nautical charts are published in different series classified as Sailing, General, Coast, Harbor, Small Craft, and Intracoastal Waterway. Chart scales range from 1:2,500 for the largest-scale harbor chart to 1:5,000,000 for the smallest-scale sailing chart. Nautical charts are constructed on the Mercator projection.

Nautical charts on issue now number about 800 and upward of 1½ million copies are distributed annually. Annual nautical chart production includes about 20 new charts, 80 new editions, and 400 new prints or reprints.

The nautical chart is designed to develop the greatest usefulness of our coastal waters and to promote safety in marine navigation through constant revisions in its contents and appearance. New surveys and resurveys of waterways and coastal topography made by the Bureau and other Federal and State agencies constantly add to the usefulness of nautical charts. Revisions in buoys, daybeacons, and lights which mark the waterways must be promptly incorporated in the charts; and charts must be redesigned to serve new types and methods of navigation.

During the past several decades the nautical chart published by the Coast and Geodetic Survey has undergone more radical changes in appearance and usefulness than in any similar period of the history of the Bureau. Several factors are responsible for the numerous significant changes in the modern chart. These are the rapid strides in surveying techniques with

Nautical chart compiler at work.



Material required for making one nautical chart.

the resulting augmented knowledge of the ocean floor, new navigational requirements, modernization by improved techniques and simplified symbolization, improved reproduction methods, and increased use of colors.

Because of improvements in navigational and surveying techniques, the nautical chart now utilizes to the fullest extent the wealth of submarine detail contained in modern hydrographic surveys. The sea floor is brought into pictorial relief by increased use of depth curves which outline significant bottom features. The navigator can then utilize the graphic profile recorded by the echo sounder, as an aid in determining his position and course. In laying a new course, these outlined features can be used as check points in areas between or beyond the limits of floating navigational aids.

Other navigational methods which have affected the content and usefulness of the nautical chart are radar and loran. Although charting of the shoreline is considered sufficient for radar navigation in most areas, the addition of contours, bluffs, elevated structures, and specific radar reflectors enhance the value of the nautical chart in this respect. General and Sailing charts are now covered with a lattice of loran lines of position to facilitate navigation by this modern electronic method.

Paralleling these advances in navigational instrumentation and equipment are the increased speed and draft of ships plying the waterways. The impact of this evolution in marine commerce is not unlike changes wrought in expediting commerce on the nation's highways. Guides to transportation like the nautical chart must improve in this accelerated era.

In contrast with the charts used in the days of slow-moving sailing vessels, which emphasized artistic detail in monochrome, the modern chart simplifies detail and utilizes colors and bold symbols for improved, quick reading. The basic detail is still printed in black including topographic contours and soundings; various other colors are used to stress certain features. All land areas are overprinted in buff; water areas between the low-water line and the curve which is considered the danger curve for that particular chart are shown in blue. Blue is also used to accent in the untinted deeper areas shallow rocks, shoals, and other dangers; green, produced by overprinting in both buff and blue, is used to define marshlands, tidal flats, and exposed ledges; and magenta is used to highlight certain floating and fixed aids to navigation and other features such as submerged cables and pipelines, danger and anchorage areas. As many as seven colors may be used on charts that show loran lines of position.

The Survey publishes a series of *Coast Pilots* which are primarily for navigational use. They provide descriptive data required by the navigator which cannot be shown conveniently on nautical charts. Each Coast Pilot covers a selected section of the coast and contains detailed data relative to the coastline and harbors, port information, sailing directions for coasting and entering harbors, and general information as to weather conditions, radio service, etc. Eight volumes are published at the present time for which new editions are issued at about 7-year intervals. Supplements containing changes and new information are published annually. Coast Pilots issued during 1964 totaled about 12,000.

Aeronautical Chart Production.—The basic series of 87 sectional aeronautical charts of the United States, previously mentioned, soon became inadequate for aircraft navigation at greater speeds and at higher altitudes. Furthermore, new radio navigational aids permitted safe all-weather flying

Aeronautical chart compiler at work.

with controlled air traffic. Additional series of charts were required for the various types of flights. Thus, a family of charts came into being that falls into two categories—for contact and instrumental flying.

Visual or contact flying.—Charts of this class are designed for contact flying with sufficient aeronautical information for the auxiliary use of radio navigational aids. They include:

LOCAL CHARTS for flights into high-density area airports.

SECTIONAL CHARTS for low-altitude and slow-to-moderate speed flights.

PLANNING CHARTS for planning flights.

WORLD CHARTS (WAC) for moderate-speed, moderate-altitude flights.

JET CHARTS for high-altitude, high-speed flights.

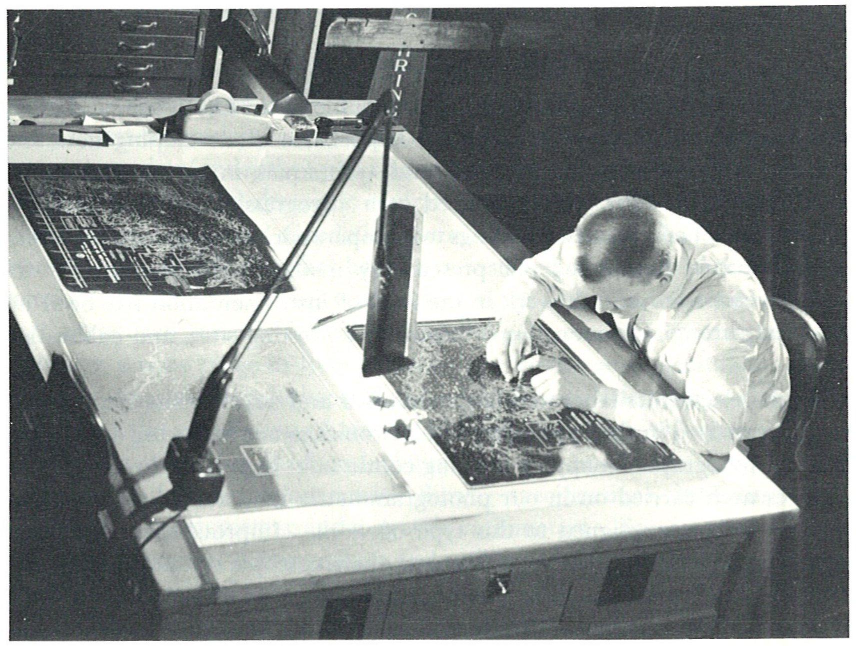
Instrument flying.—The instrument series carries full aeronautical information for all-weather flights and is practically devoid of any topographic information that can be used for visual landmarks. They consist of:

ENROUTE CHARTS for navigation by radio aids only.

INSTRUMENT APPROACH AND PROCEDURE CHARTS showing flight patterns at airports.

AIRCRAFT POSITION CHARTS for plotting positions over the principal oceanic routes used by civil aviation.

About 7 million copies of the 189 charts of the visual series on issue and nearly 27 million copies of the 1,735 instrument charts are printed annually for civilian use.



Negative engraver working on a nautical chart.

In the interest of safety, it is necessary to keep the charts as current as practicable. Charts of the Sectional and WAC series are revised one to two times yearly to reflect the latest changes in landmarks, hazardous obstructions, airport data, and radio aids. The radio navigation charts, however, must be kept current to an even higher degree as the pilot flying the airways entirely on instruments, in bad weather, is dependent upon the absolute accuracy of the information portrayed. The enroute charts are issued every 28 days just prior to the time that major changes in the airspace structure become effective. Similarly, the instrument-approach procedure charts are published just prior to the effective date of a new or revised instrument-approach procedure.

A staff of highly skilled researchers, cartographers, and technicians is required to ensure the usefulness and reliability of the charts. The needs of pilots and navigators of military aircraft, scheduled airlines, business aircraft, and private planes must be determined and correlated. Aeronautical and topographic information needs to be gathered, evaluated, and disseminated to chart compilers. The cartographers must present the information in a clear, concise manner, giving emphasis to items of major importance. Close coordination is required with other governmental agencies and rulemaking bodies to ensure that all rules and regulations affecting aeronautical charts are properly portrayed. Schedules must be prepared and maintained for the compilation, reproduction, and distribution of all the series in order that the right charts are available at the right places at the right times.

Research and Development

Because of its highly specialized activities, the Coast and Geodetic Survey has from its inception recognized the importance of developing new and improved instruments, equipment, and techniques in order that better results might be obtained at reduced cost. Progressive research with the application of new scientific findings to our operations has been of paramount importance in developing our present-day methods and equipment. In recent years our research work in the field of instrumentation has been intensified through maintenance of laboratories, testing sites, and calibration areas.

In the electronics laboratory improvements and adjustments are made of equipment used in the application of electronics to our surveying operations. Aerial photographic mapping is being continually improved through intensive research carried on in our photogrammetric laboratory by a technical group of experts assigned to this type of work. Improvements are being made in the quality, accuracy, and speed of stereoscopic contouring with the recently developed first-order plotters and in the field of aerotriangulation. A feature of the magnetic observatory at Fredericksburg, Va., is an array of large coils permitting the duplication of the geomagnetic field at any spot on the globe, which is extremely useful in testing instruments. The new seismological laboratory in Albuquerque, N. Mex., besides being a first-class observatory where many instruments are operated, is engaged in the calibration of, as well as in research and development work on, seismological instrumentation. The Survey maintains modern repair shops for servicing all instruments and equipment used in its field and office work.

Many important improvements in operating equipment and methods used in hydrographic surveying have resulted in extensive modernization in the field of hydrography. Work now in progress includes the design and development of automatic loggers to record hydrographic data for machine processing and eventual automatic plotting of charts. Also the development of a new hydrographic launch and a landing craft to handle cargoes of up to 3 tons. To meet the special needs of the Survey, an aluminum shoal-water hydrographic launch has been designed and is now undergoing field tests. Improvements have been made in our tide and current instruments, including modification of the NK–7 portable depth recorder for use as a tide gage.

To meet the needs of all-purpose, oceanwide surveys the design and development of new instruments include the following: a precision deep-sea echo sounder with narrow-beam, mechanically stabilized transducer to improve resolution of bottom features; operational use of the geological echo profiler (GEP), a pulsing sound reflection device utilizing simulated explosions as a sound source to record subbottom geological horizons; and oceanographic sensors to measure and automatically record depth, temperature, salinity, and sound velocity, currents, pressure changes, and tidal wave characteristics.

The deep-sea anchoring equipment installed aboard the larger ships provides the capability of anchoring and taking bottom samples and cores from the greatest ocean depths, as well as the capability for electrical or electronic instrumentation for depths up to 10,000 feet.

New and improved electronic equipment has been designed for seismological work at Coast and Geodetic Survey observatories. Improved visible remote seismograph recorders have been installed at several stations in connection with the seismic sea wave warning service. An improved method was introduced recently for calibrating the galvanometric seismographs by imposing a wide range of frequencies on the seismometer pendulum.

Laboratory tests simulating tide and seiche action at detector stations have facilitated the installation of sea wave detectors. Standard types of magnetic instruments for field and observatory use have been designed and manufactured in accordance with Survey specifications, including earth inductors, magnetometers, and magnetic variometers. Special photographic recorders for use in Arctic regions and visible recorders for observatory use, have been developed.

The development of an automatic standard magnetic observatory represents a major innovation in the collection and handling of geomagnetic data. This instrument, when fully developed, will produce the statistical output characteristics of standard observatories automatically. Ideally, this will mean that all geomagnetic components of the earth's magnetic field are recorded in a way that permits immediate machine computation, transcribing the raw data directly into usable form at a very rapid rate.

A new induction-type magnetometer, developed with the cooperation of the Naval Ordnance Laboratory and its successful adaptation to aircraft use by the Coast and Geodetic Survey, has for the first time opened the way to immediate future airborne magnetic surveying of ocean areas and other regions inaccessible by ordinary methods. Beginning in 1960, towed total-intensity magnetometers have been operated extensively by our ships at sea. Observations of this type, readily conducted in conjunction with other hydrographic and oceanographic operations, yield information of great value for studies of the ocean floor geology, at a relatively minor cost in time and equipment. They are also of material benefit in the regular chart program.

In a program to expand the measurement of diurnal variations of the earth's magnetic field, the Bureau is conducting research on a stable, submerged platform system for the placement of underwater magnetometers and other deep-water sensors. This program consists of two essentially separate parts. The first part is that of establishing the feasibility of placing a platform 100 or 200 feet beneath the surface in very deep water and in determining just how stable it is. Tests on a buoy submerged about 100 feet beneath the surface, in 500 feet of water, and held down by three cables anchored on an equilateral triangle base, indicated that the platform tilted and rotated with an amplitude of approximately 0°.5 from its mean position. The second part is the development of a suitable three-component magnetometer compatible with the platform.

Detailed studies of the configurations of the earth's field and of its temporal changes have led to significant advances in our understanding of phenomena seated deep in the earth as well as in the ionosphere and the regions beyond, where the geomagnetic field is a predominant environmental factor. In addition, an energetic program is promoted in the Survey for working out new techniques and developing new instruments for the highly refined measurements that provide the basis of an all-out program of magnetic work.

In 1948, the Coast and Geodetic Survey installed its first group of electronic computers to use primarily the punchcard method. These machines are standard equipment in many large business firms. Geodetic, magnetic, seismological, photogrammetric, tidal analysis, and cartographic computations are being made on the machines. Many of the extensive geodetic problems being solved by this method include large sets of simultaneous equations involved in triangulation adjustments. Such problems comprising more than 2,000 simultaneous equations are being completed in 3 or 4 months. Using desk calculators, the services of five men would be required for 1 year to solve the same problem.

Plans have been made for expanding geodetic control into northern Alaska by means of shoran trilateration. This method offers a rapid means of locating stations for which more accurate determinations can be made at a later date by conventional triangulation.

The sea gravity program has been expanded and a gravity meter check range was established in the San Francisco area with navigational control adequate for eliminating the long-period effects of horizontal and vertical accelerations.

A satellite triangulation program based on the simultaneous optical tracking of passive satellites from three or more tracking stations is under development. By a proper selection of station sites and satellites, a triangulation network for continental or even intercontinental extent can be developed. This technique would have the capability of accurately relating positions of isolated and distant points on the earth's surface.

Extensive operations by the Bureau in Alaska require the development of suitable instrumental equipment and methods appropriate to the unique rigorous environmental conditions encountered in the Arctic and subarctic.

All types of precise instruments require special modification to withstand the intense cold and humid conditions of Alaska. Through experimentation employing temperature chamber equipment the best metals and oils for instruments and equipment are being determined.

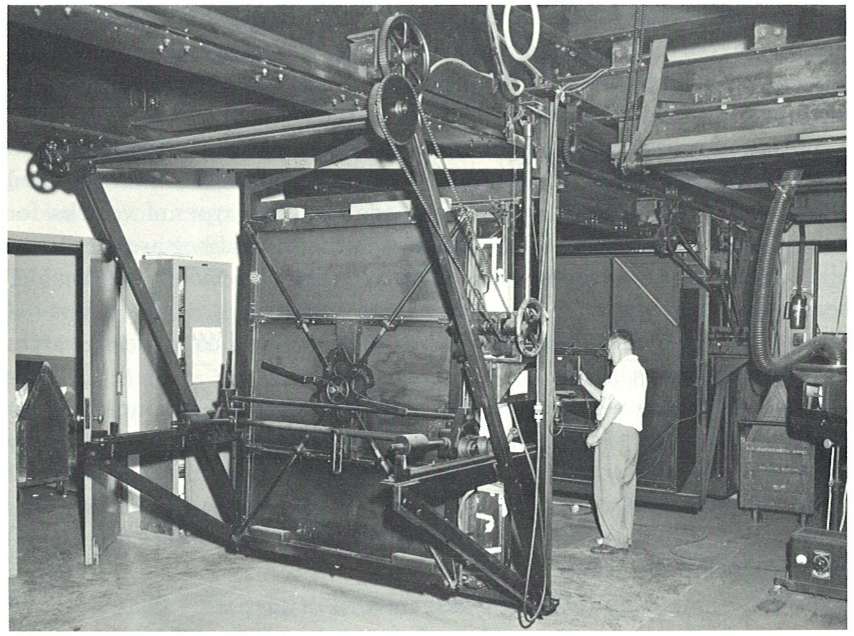
Improved procedures are in prospect for determining elevations through the development of techniques for use of photo-theodolites and precision altimeters. Experimentation is being made with new types of vehicles for surveys in inaccessible places such as Alaskan tundra and bog areas. Techniques have been developed for landing amphibious vehicles over boulder beaches and through rough surf. Surveying operations are being expedited through the use of helicopters for placing personnel and equipment in areas not otherwise accessible.

Research and development in cartographic and photolithographic methods and techniques for map and chart production has been carried on by the Bureau for many years. The contributions of research in these special fields and their further application to the entire graphic arts industry has helped place the Bureau in an enviable position of leadership among the map-producing agencies of the world.

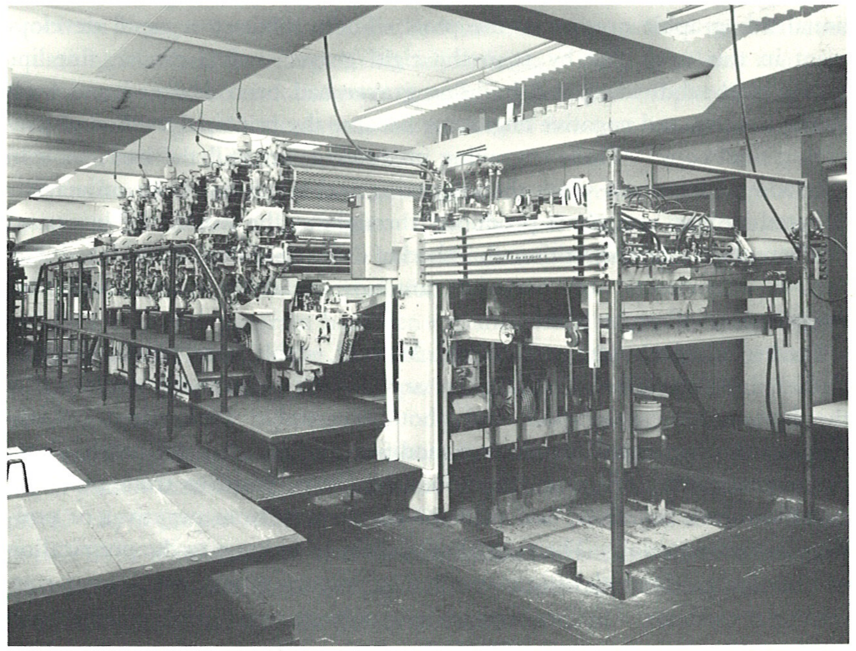
Negative engraving (scribing) as a method of preparing final map and chart copy for both new chart production and the revision of existing charts was pioneered and developed by the Bureau. In 1935, special emphasis was placed on the design of instruments specifically suited for the engraving technique and the first instrument was built that departed from the traditional lithographic needles of the past. There followed a rapid development in this work and by 1940 the rigid graver, swivel graver, fine-line graver, and subdividing and building graver had been designed and built by the Bureau, and negative engraving became the principal method of preparing final copy. These engraving instruments are still the basic tools in use today. In recent years the engraving technique has been universally adopted by map and chart producers throughout the world and has practically replaced the conventional method of drafting with pen and ink. The various instruments and materials are now available commercially for engraving on glass or plastic.

During the early stages of World War II, stable base plastic sheeting attracted the attention of mapmakers and its uses were quickly exploited by the Bureau for cartographic and photolithographic applications. Techniques were developed employing modified surface and deep-etch platemaking methods to produce blacklines, bluelines, positives from positives, negatives from negatives, and color proofs directly from negatives or positives on this material. The extension of these techniques to the preparation of tints for gradient elevations resulted in important economies over conventional methods. In recent years new polyester and other plastics have taken their place in cartographic and reproduction uses.

The combination of tones of the same color on one printing plate offers many advantages of economy and accuracy in the press. The Bureau de-



Fifty-inch precision camera used in chart making.



Five-color offset press. This press has an operating speed of 6,000 impressions per cylinder per hour.

veloped techniques for the manufacture of large-size dot and ruling screen films in a wide range of tone values. These screen films are interposed between the negative and the plate at the time of platemaking, thus permitting the use of open negatives with corrections. Copies of these screen films have been supplied at a nominal cost to commercial and Government printers throughout the world.

Unprecedented accomplishments in the field of cartography and photolithography during the modern age of scientific discovery and development are resulting in refinements of methods, new types of cartographic materials, and vastly improved equipment undreamed of a few decades ago. Intensive research and development programs that are expected to continue in these areas will be reflected in still greater achievements in map and chart production.

Present Operations and Plans for the Future

The Coast and Geodetic Survey is now fulfilling its assigned tasks in furthering the national objectives in oceanography. The national goal is to comprehend the world ocean, its boundaries, its properties, and its processes, and to exploit knowledge thus acquired in the public interest, in the enhancement of our security, our culture, our international posture, and our economic growth.

In view of the strategic importance of Alaska, major emphasis is being placed on the extension of our hydrographic surveys in the area. Survey vessels operate during the summer working seasons in various Alaskan waters. Other hydrographic surveys are carried on in various regions along the Atlantic, Gulf, and Pacific coasts of the United States as a part of the program of continuously revising and updating our nautical charts. Wire drag surveys for locating sunken wrecks and dangers to navigation are conducted in New England, Alaska, or in other areas as the need arises.

Aerial photographs are taken regularly of areas along the Atlantic and Gulf coasts and in Alaska. Photographs are also taken of many airports in the United States; surveys are completed annually for over 150 airports for use in compiling aeronautical charts for making instrument approaches and landings and for airport obstruction plans. Photogrammetric field survey parties are working along the coasts of the United States and its possessions.

The basic networks of horizontal and vertical control are being extended in the United States and in the interior of Alaska. Special geodetic field projects are being assigned as needed to provide data for the various nationwide programs.

Our present program of tidal observations is carried on at the principal seaports in the United States and possessions and in foreign areas to provide data for prediction of tides and studies of mean sea level. The collection of temperatures and densities of sea water at tide stations is a continuing operation and a number of new stations are added to the network each year.

Data are provided regularly for further mapping of seismic areas and for the development of safe building-construction methods by the chain of seismograph stations maintained by the Survey. Data thus obtained are supplemented with information furnished by universities and private institutions. Annually over 250,000 earthquake messages are received through national and international cooperating agencies; announcements are made of the locations of more than 5,000 earthquakes.

Plans for the future include an accelerated program in support of the economic and industrial expansion of the Nation. More complete coverage of geodetic control, basically essential in the national highway building program, the President's water resources program, and a variety of other purposes, will be supplied to meet anticipated demands. At the same time, we propose to extend a network of about 15 supergrade traverse surveys crossing the lower 48 States in north-south and east-west directions. The geodetic program of the Bureau provides basic data essential to all large-scale engineering activities concerned with development of resources.

Intensive hydrographic surveys out to the edge of the continental shelf is a challenging task for which detailed planning is required. The Outer Continental Shelf Lands Act claims for the United States the vast underwater area extending from the shoreline to the continental slope comprising more than 2 million square miles, together with the resources beneath the ocean floor. Detailed and accurate nautical charts, showing clearly the bottom characteristics of this marginal sea, are essential to the development of these resources of the future.

Other plans for the future include expanded programs in tide and current work, aeronautical charting, and geophysical research. Already geophysical and geodetic research in the Coast Survey have provided valuable data for the defense of the Nation and the advancement of science and engineering.

Many of the present practices and techniques used by the Bureau in both office and field were first presented informally in publications issued more or less periodically since 1930. These publications provide a medium for exchanging ideas between our scientifically trained officers and employees on widely separated assignments in engineering work. Through these informal technical discussions officers keep in touch with and receive the maximum benefit from the efforts and experiences of one another. New methods and new developments are thus exposed to discussion and modification and made available to field parties for trial or application. No regular schedule is maintained but the material is printed as it accumulates and at such intervals as to be of maximum use to operating units. In addition to being of great value to the Survey, the publications render indirectly a valuable public service.

The work of the Coast and Geodetic Survey is a pioneering effort which has expanded progressively in scope and importance with the increased demands for our products. The development and extension of our technical services and their importance in contributing to the general welfare of

the Nation are apparent. Each successive decade has seen a broadening of our operations with improved techniques and methods.

The plans of future operations are constantly being revised to keep pace with the latest developments in commerce and industry and to meet the increased demands made upon us in preparing for national defense. Our labors must continue with unabated vigor so long as the sea washes our coasts, rivers flow and deposit their silt, earthquakes occur, and other changes are made by man and Nature. The necessary services performed by the Coast and Geodetic Survey reveal their value in the inestimable wealth of added security to life and property on land and sea.

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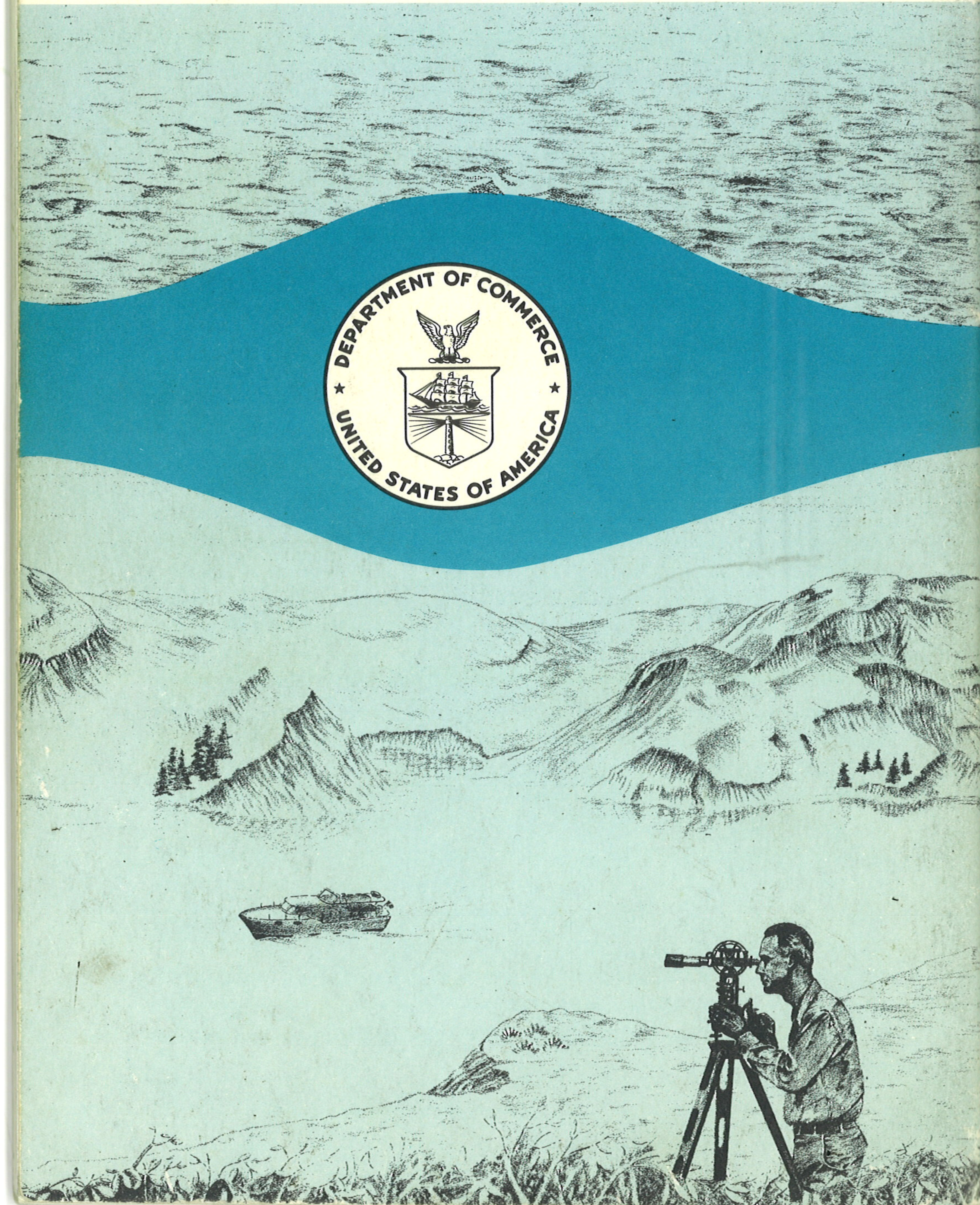
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